NASA TECHNICAL MEMORANDUM

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SOLID ROCKET BOOSTER THRUST VECTOR CONTROL SUBSYSTEM VERIFICATION TEST (V-2) REPORT

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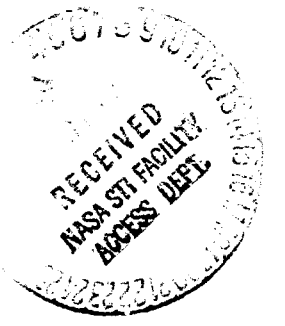

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Introduction

The purpose of this report is to present a summary of the certification phase V-2 testing results conducted on the TVC subsystem, dedicated to the technical evaluation of this flight system.

The TVC subsystem, located on the aft skirt of the SRB, provides pitch, roll and yaw movements, as required, by the guidance and control system of the orbiter. It consists of two separate hydraulic power systems which supply power to the SRB gimbal actuators in response to the orbiter commands. These two systems operate together, and they are adapted so that when one of these systems fail, the surviving module increases its output horsepower by increasing the turbine speed, and in this way, satisfy the total TVC subsystem demand.

The TVC subsystem (Figure 1) was installed in MSFC test stand 500 and different tests ran to verify the overall operational characteristics. It was subjected to a total of 66 hot firing starts and 9089 seconds of operation in rock system and 9068.4 seconds on tilt system (See Tables 1 and 2). GN_2 spin tests performed on the TVC subsystem totalled 66 starts with 12950.8 seconds for rock, and 51 starts with 12265.5 seconds for tilt. (See Tables 3 through 6). Of the 66 hot firing starts, 59 were completed.

The testing done during V-2 phase was divided into three parts: horizontal, van, and vertical tests. The purpose of the horizontal test was to demonstrate that the V-3 (TVC subsystem with the aft skirt) can be tested in that position and to develop hydraulic servicing procedures. Additional bleeding and purging techniques were developed and additional bleed hardware was employed to facilitate horizontal bleeding. The total number of hot firings was three with 238.5 seconds on both systems. The KSC hot firing van tests were done for the following reasons:

(1) to verify the operation of the TVC with this portable test facility, (2) to train USBI personnel on testing operations, and (3) to develop a data base to support the runs at KSC. The total number of hot firings was 12 with 1745 seconds of operation time on rock system and 1737 seconds on tilt system.

All the testing done was with a load over the actuator to simulate the nozzle. The gimbal programs (See Figures A-1 through A-16) consisted of different ramps (up to 5 deg/sec gimbal rate), step commands and sine wave inputs. Also, in some of these tests, the APU was commanded to 110 and 112 percent turbine speed to verify the operation of the TVC subsystem in these modes.

Test Objectives

- Verify that the SRB TVC subsystem meets some of the level II performance requirements under controlled loaded conditions.

- Build up a data base for support of flight and solid rocket motor static firings.

- To verify GN_2 spin test procedures and build up data base for correlation with launch site verification of the TVC subsystem.

- To verify ground servicing procedures.

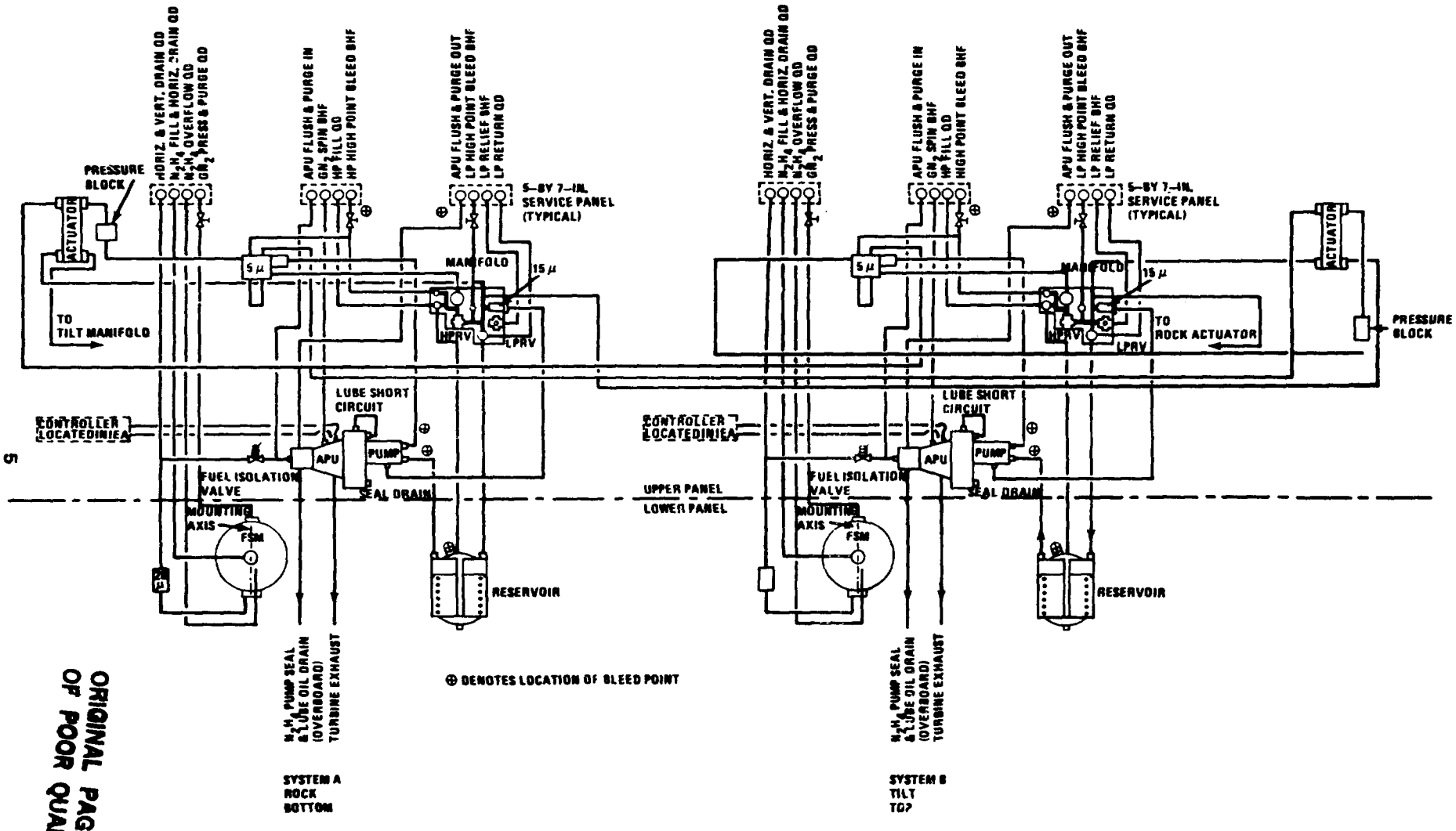
- To verify and implement changes required by component tests and/or design reviews.

Hardware Identification
V-2 Verification Testing

Hardware Configuration: Verification Hot Firing Assembly

Drawing No.: 13A10180, Rev. A

		System A	System B
Components:	P/N	S/N	S/N
APU	13A10010	102	101
Hydraulic Pump	13A10038	156850	15843
Hydraulic Manifold	13A10037	004	005
Hydraulic Reservoir	13A10036	0008	0005
Actuator	16A03000	004	002
FSM	13A10009-1	004	005
FIV	13A10041	0002	0001
Check Valve/ Filter Assembly	13A10042	009	010
Quick Disconnects (24 of them)	13A10050	-	-
Hand Valves	20M85007-1	-	-



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THRUST VECTOR CONTROL (TVC) SUBSYSTEM SCHEMATIC

FIGURE 1

TABLE 1

V-2 VERIFICATION TESTING (HORIZONTAL)
SUMMARY OF HOT FIRINGS

TEST NO	RUNTIME (SEC)		PROGRAM	DATE	REMARKS
	A	B			
P037 – 024	20	20	C	2/3/78	FULL DURATION – SUCCESSFUL
– 025	72.5	72.5	SPECIAL	2/8/78	FULL DURATION – SUCCESSFUL
– 026	146	146	FI	2/9/78	FULL DURATION – SUCCESSFUL

TABLE 2

V-2 VERIFICATION TESTING (VERTICAL)
SUMMARY OF HOT FIRINGS

TEST NO.	RUNTIME (SEC) A	RUNTIME (SEC) B	PROGRAM	DATE	REMARKS
P037 – 062	20	20	CI	6/30/78	APU CONTROL VALVES LEAKED IN BOTH SYSTEMS
– 066	2.6	25.2	FI	7/12/78	CUTOFF DUE TO INSTRUMENTATION PROBLEMS
– 067	160	160	FI	7/13/78	FULL DURATION – SUCCESSFUL
– 068	75.3	6.6	G	7/13/78	CUTOFF – LOW HYDRAULIC FLUID SUPPLY PRESSURE ON SYSTEM B CAUSED BY ACTUATORS STARTING IN OFF – NULL POSITION. CONSEQUENTLY APU A GIMBALED BOTH ACTUATORS UNTIL 75 SECONDS (SECOND CUTOFF WAS AT THE START OF 5 DEG/SEC. RAMP IN BOTH ACTUATORS)
– 069	160	160	G	7/14/78	FULL DURATION – SUCCESSFUL
– 070	160	160	D	7/14/78	FULL DURATION – SUCCESSFUL
– 071	160	160	F2	7/19/78	FULL DURATION – SUCCESSFUL
– 072	160	160	H	7/19/78	FULL DURATION – SUCCESSFUL
– 074	160	160	F2	7/21/78	FULL DURATION – SUCCESSFUL
– 075	160	160	E	7/21/78	FULL DURATION – SUCCESSFUL
– 076	160	160	E	7/24/78	FULL DURATION – SUCCESSFUL
– 077	160	160	G	7/24/78	FULL DURATION – SUCCESSFUL
– 078	152	152	D	7/24/78	CUT OFF DUE TO INSTRUMENTATION PROBLEMS WITH TAPE PROGRAM (AT THE END) – THE MISSION WAS COMPLETED.
– 79	33.6	2.9	E	7/26/78	UNDERSPEED CUT OFF ON SYSTEM B
– 80	11.9	3.7	E	7/26/78	UNDERSPEED CUT OFF ON SYSTEM B
– 81	160	160	E	8/1/78	FULL DURATION – SUCCESSFUL
– 82	150.5	150.5	J	8/1/78	CUT OFF DUE TO HIGH LUBE OIL TEMPERATURE AFTER THE END OF THE GIMBAL PROGRAM – COMPLETE MISSION

TABLE 2

V-2 VERIFICATION TESTING (VERTICAL)
SUMMARY OF HOT FIRINGS (CONT.)

TEST NO.	RUNTIME (SEC) A	RUNTIME (SEC) B	PROGRAM	DATE	REMARKS
P037 – 083	160	160	N*	8/1/78	FULL DURATION
– 084	160	160	D	8/1/78	FULL DURATION
– 085	160	160	N*	8/2/78	FULL DURATION
– 086	160	160	E	8/2/78	FULL DURATION
– 087	160	160	D	8/3/78	FULL DURATION
– 088	88.4	160	D	8/3/78	CUT OFF SYSTEM A LUBE OIL TEMPERATURE HIGH
——	——	—	——	8/7 – 8/22	INSTALLATION OF KSC HOT FIRING VAN
– 096	20	20	CI	8/28/78	FULL DURATION
– 097	160	160	D	8/29/78	FULL DURATION
– 098	125	117	N*	8/30/78	OBSERVER'S CUT OFF – USE OF THE WRONG SCALE IN GAS GENERATOR PRESSURE MEASUREMENT.
– 099	160	160	N*	8/31/78	FULL DURATION
– 100	160	160	I	8/31/78	FULL DURATION
– 101	160	160	N*	9/7/78	FULL DURATION
– 102	160	160	D	9/8/78	FULL DURATION
– 103	160	160	N*	9/11/78	FULL DURATION
– 104	160	160	I	9/11/78	FULL DURATION
– 105	160	160	D	9/13/78	FULL DURATION
– 106	160	160	N*	9/13/78	FULL DURATION
– 107	160	160	D	9/15/78	FULL DURATION
				9/15 – 9/18	CHANGE TO ORIGINAL INSTALLATION (BLOCK HOUSE)
– 108	160	160	D	9/19/78	FULL DURATION

TABLE 2

V-2 VERIFICATION TESTING (VERTICAL)
SUMMARY OF HOT FIRINGS (CONT.)

TEST NO	RUNTIME (SEC) A	RUNTIME (SEC) B	PROGRAM	DATE	REMARKS
P037 – 109	112	112	L	9/27/78	FULL DURATION
– 110	160	160	G	10/6/78	FULL DURATION (100 PERCENT TURBINE SPEED)
– 111	160	160	N*	10/6/78	FULL DURATION
– 112	146	146	M	10/6/78	FULL DURATION
– 113	160	160	D	10/6/78	FULL DURATION
– 114	94	94	F3	10/16/78	OBSERVER'S CUT OFF – ACTUATOR PREFILTRATION VALVE WAS OPEN DURING FIRING
– 115	160	160	F3	10/16/78	FULL DURATION
– 116	160	160	D	10/17/78	FULL DURATION
– 117	160	160	E	10/18/78	FULL DURATION
– 118	160	160	D	10/19/78	FULL DURATION
– 119	160	160	H	10/20/78	FULL DURATION
– 120	160	160	D	10/23/78	FULL DURATION
– 121	160	160	D	10/24/78	FULL DURATION
– 122	160	160	E	10/25/78	FULL DURATION
– 123	160	160	I	10/26/78	FULL DURATION
– 124	160	160	E	10/27/78	FULL DURATION
– 131	160	160	F3	1/24/79	FULL DURATION
– 158	160	160	D	3/26/79	FULL DURATION
– 159	160	160	D	3/29/79	FULL DURATION
– 160	80	80	C2(4)	3/30/79	FULL DURATION
– 161	60	60	C2(3)	3/30/79	FULL DURATION
– 162	160	160	J	4/2/79	FULL DURATION
– 163	160	160	E	4/3/79	FULL DURATION

TABLE 2

V-2 VERIFICATION TESTING (VERTICAL)
SUMMARY OF HOT FIRINGS (CONT.)

TEST NO	RUNTIME (SEC)		PROGRAM	DATE	REMARKS
	A	B			
P037 – 164	160	160	G	4/4/79	FULL DURATION
– 165	160	160	G	4/10/79	FULL DURATION
– 166	160	160	FI	4/10/79	FULL DURATION
– 167	160	160	G	4/11/79	FULL DURATION

TABLE 3

V-2 VERIFICATION TESTING (HORIZONTAL)

GN_2 SPIN TESTS

SYSTEM A

TEST NO	TEST DURATION (SEC)	DATE
P037-002	15	1/18/78
P037-003	16	1/18/78
P037-006	20	1/25/78
P037-007	10	1/25/78
P037-010	9	1/30/78
P037-011	23	1/30/78
P037-012	238	1/30/78
P037-013	300	1/30/78
P037-016	9.5	2/01/78
P037-017	9	2/01/78
P037-018	14.5	2/01/78
P037-019	302	2/02/78
P037-022	302	2/02/78
P037-023	324.7	2/03/78
TOTAL 14 TESTS	1592.7 SEC.	

TABLE 4

V-2 VERIFICATION TESTING (HORIZONTAL)

GN_2 SPIN TESTS

SYSTEM B

TEST NO	TEST DURATION (SEC)	DATE
P037-004	15.5	1/18/78
P037-005	15	1/18/78
P037-008	10	1/25/78
P037-009	11.5	1/26/78
P037-014	270	2/01/78
P037-015	300	2/01/78
P037-020	301.5	2/02/78
P037-021	302	2/02/78
TOTAL 8 TESTS	1225.5 SEC.	

TABLE 5

V-2 VERIFICATION TESTING (VERTICAL)
SUMMARY OF GN_2 SPINS

TEST NO.	RUNTIME (SEC)		DATE	REMARKS
	A	B		
42	2.6	0	6/23/78	LOW SPIN PRESSURE – CUTOFF
43	3.1	0	6/23/78	LOW SPIN PRESSURE – CUTOFF
44	3.3	0	6/23/78	LOW SPIN PRESSURE – CUTOFF
45	30	0	6/23/78	LOW SPIN PRESSURE
46	30	0	6/23/78	LOW SPIN PRESSURE
47	0	30	6/26/78	LOW SPIN PRESSURE
48	0	30	6/26/78	LOW SPIN PRESSURE
49	0	150	6/26/78	HIGH SPIN PRESSURE
50	0	150	6/26/78	HIGH SPIN PRESSURE
51	150	0	6/26/78	HIGH SPIN PRESSURE
52	150	0	6/26/78	HIGH SPIN PRESSURE
53	28.2	0	6/28/78	HIGH SPIN PRESSURE – CUTOFF
54	300	0	6/28/78	HIGH SPIN PRESSURE
55	0	300	6/28/78	HIGH SPIN PRESSURE
56	300	0	6/28/78	HIGH SPIN PRESSURE
57	0	300	6/28/78	HIGH SPIN PRESSURE
59	9.1	0	6/30/78	HIGH SPIN PRESSURE – CUTOFF
60	300	0	6/30/78	HIGH SPIN PRESSURE
61	0	300	6/30/78	HIGH SPIN PRESSURE
64	300	0	7/12/78	HIGH SPIN PRESSURE
65	0	300	7/12/78	HIGH SPIN PRESSURE

TABLE 5

GN_2 SPIN
VERTICAL TESTING (CONT)

TEST NO.	RUNTIME (SEC)		DATE	REMARKS
	A	B		
155	60	60	3/26/79	LOW SPIN PRESSURE BOTH
156	300	0	3/26/79	HIGH SPIN PRESSURE ROCK
157	0	300	3/26/79	HIGH SPIN PRESSURE TILT
168	300	0	4/23/79	HIGH SPIN PRESSURE ROCK
169	0	300	4/23/79	HIGH SPIN PRESSURE TILT
170	300	0	4/23/79	HIGH SPIN PRESSURE ROCK
171	0	300	4/23/79	HIGH SPIN PRESSURE TILT
172	300	0	4/23/79	HIGH SPIN PRESSURE ROCK
173	0	300	4/23/79	HIGH SPIN PRESSURE TILT
174	300	0	4/23/79	HIGH SPIN PRESSURE ROCK
175	0	300	4/23/79	HIGH SPIN PRESSURE TILT
176	75	0	4/24/79	HIGH SPIN PRESSURE ROCK
177	300	0	4/24/79	HIGH SPIN PRESSURE ROCK
178	0	300	4/24/79	HIGH SPIN PRESSURE TILT
179	300	0	4/24/79	HIGH SPIN PRESSURE ROCK
180	0	300	4/24/79	HIGH SPIN PRESSURE TILT
181	300	0	4/24/79	HIGH SPIN PRESSURE ROCK
182	0	300	4/24/79	HIGH SPIN PRESSURE TILT
183	300	0	4/26/79	HIGH SPIN PRESSURE ROCK
184	0	300	4/26/79	HIGH SPIN PRESSURE TILT
185	300	0	4/26/79	HIGH SPIN PRESSURE ROCK
186	0	300	4/26/79	HIGH SPIN PRESSURE TILT
187	142.5	0	4/26/79	HIGH SPIN PRESSURE ROCK

TABLE 5

GN_2 SPIN

VERTICAL TESTING (CONT.)

TEST NO.	RUNTIME (SEC)		DATE	REMARKS
	A	B		
188	0	300	4/26/79	HIGH SPIN PRESSURE TILT
189	300	0	4/30/79	HIGH SPIN PRESSURE ROCK
190	0	300	4/30/79	HIGH SPIN PRESSURE TILT
191	300	0	4/30/79	HIGH SPIN PRESSURE ROCK
192	0	300	4/30/79	HIGH SPIN PRESSURE TILT
193	300	0	4/30/79	HIGH SPIN PRESSURE ROCK
194	0	300	4/30/79	HIGH SPIN PRESSURE TILT
195	0	60	6/6/79	LOW SPIN PRESSURE TILT
196	300	0	6/7/79	HIGH SPIN PRESSURE ROCK
197	0	300	6/7/79	HIGH SPIN PRESSURE TILT
198	300	0	6/8/79	HIGH SPIN PRESSURE ROCK
199	0	300	6/8/79	HIGH SPIN PRESSURE TILT
200	300	0	6/11/79	HIGH SPIN PRESSURE ROCK
201	0	300	6/11/79	HIGH SPIN PRESSURE TILT
202	300	0	6/11/79	HIGH SPIN PRESSURE ROCK
203	0	300	6/11/79	HIGH SPIN PRESSURE TILT
204	300	0	6/12/79	HIGH SPIN PRESSURE ROCK
205	0	300	6/12/79	HIGH SPIN PRESSURE TILT
206	300	0	6/12/79	HIGH SPIN PRESSURE ROCK
207	0	300	6/12/79	HIGH SPIN PRESSURE TILT
208	300	0	6/12/79	HIGH SPIN PRESSURE ROCK
209	0	300	6/12/79	HIGH SPIN PRESSURE TILT
210	300	0	6/13/79	HIGH SPIN PRESSURE ROCK

TABLE 5

GN_2 SPIN
VERTICAL TESTING (CONT.)

TEST NO.	RUNTIME (SEC)		DATE	REMARKS
	A	B		
211	0	300	6/13/79	HIGH SPIN PRESSURE TILT
212	300	0	6/13/79	HIGH SPIN PRESSURE ROCK
213	0	300	6/13/79	HIGH SPIN PRESSURE TILT
214	300	0	6/13/79	HIGH SPIN PRESSURE ROCK
215	0	300	6/13/79	HIGH SPIN PRESSURE TILT
216	300	0	6/13/79	HIGH SPIN PRESSURE ROCK
217	0	300	6/13/79	HIGH SPIN PRESSURE TILT
218	300	0	6/13/79	HIGH SPIN PRESSURE ROCK
247	300	300	7/26/79	HIGH SPIN PRESSURE BOTH
248	300	300	7/26/79	HIGH SPIN PRESSURE BOTH
249	300	300	7/26/79	HIGH SPIN PRFSSURE BOTH
250	300	300	7/26/79	HIGH SPIN PRESSURE BOTH
251	300	300	7/26/79	HIGH SPIN PRESSURE BOTH

TABLE 6

GN_2 SPIN

VERTICAL TESTING (VAN)

TEST NO	RUNTIME (SEC)		DATE	REMARKS	
	A	B			
89	2	0	8/22/78	LOW SPIN PRESSURE	CUTOFF
90	2	0	8/23/78	LOW SPIN PRESSURE	CUTOFF
91	30 (2)	0	8/24/78	LOW SPIN PRESSURE	
92	0	30 (2)	8/24/78	LOW SPIN PRESSURE	
93	110.3	0	8/25/78	HIGH SPIN PRESSURE	CUTOFF
94	300	0	8/25/78	HIGH SPIN PRESSURE	
95	0	300	8/25/78	HIGH SPIN PRESSURE	

History of Hot Firings

V-2 Testing in Horizontal Position

Test P037-024 was conducted successfully on February 3, 1978. The purpose of this test was to verify the hardware and software prior to a full duration test (160 seconds). The test duration was 20 seconds, and the "C" Gimbal Program (KSC Checkout Profile) was used on the actuators.

Test P037-025 was conducted successfully on February 8, 1978. The purpose of this test was to compare the data from test P037-024: 1 degree step commands to a 5 degree/second ramp rate. As a result of this firing, it was determined that the 5 degree/second ramps were more suitable for the KSC checkout profile than the step commands. This lasted 72.5 seconds and the "special" Gimbal Program was used on the actuator.

Test P037-026 was conducted on February 9, 1978. The purpose of this test: to run a full duration (160 seconds) firing using the F1 Gimbal Program was accomplished without any problems.

NOTE: All the verification testing done in horizontal position was performed with unloaded actuators.

V-2 Testing in Vertical Position

Test P037-062 was conducted on June 30, 1978. This test ran the modified KSC checkout profile, CI Gimbal Program, (See Fig. A-2). During a post test inspection, hydrazine was found in the tail pipe fitting of both APU's. The data showed that the APU control valves leaked during this test. These valves did not pass the leak check. Consequently, they were replaced to prevent major problems. It was determined later that these valves were contaminated during the hydrazine servicing prior to the hot firing. No other anomalies were found in this firing. This run lasted 20 seconds.

Test P037-066 was conducted on July 12, 1978. This test ran the F1 Gimbal Program (See Fig. A-6) for 160 seconds. This firing was aborted after the APU low turbine speed cutoff in the rock system (55,000 rpm cutoff redline) was activated at 2.5 seconds instead of the normal 4 seconds resulting in an APU shutdown during start transient. This problem was attributed to a facility electronic problem. Tilt APU was cut manually at 25.2 seconds. A post test inspection and data analysis revealed no other problems during hot firing operation.

Test P037-067 was conducted on July 13, 1978, as a repeat of test P037-066. This time, the TVC ran successfully for 160 seconds.

Test P037-068 was conducted on July 13, 1978. This test ran the G Gimbal Program (See Fig. A-9) for 160 seconds; but, the test was aborted after a premature cutoff due to low hydraulic fluid supply pressure on the tilt system. This was caused by the actuator being off-null prior to start because of a procedural error. No system anomalies were observed and rock system continued operation under the backup mode until 75 seconds when this APU could not supply enough power when both actuators were commanded to a 5 deg/sec gimbal rate. (Under this mode, the APU can supply power up to a maximum of 3.2 deg/sec actuator gimbal rate.)

Test P037 069 was conducted on July 14, 1978, as a repeat of test P037-068. This time, the TVC ran successfully for 160 seconds.

Test P037-070 was conducted on July 14, 1978, and the Nominal Flight Mission Gimbal Program, Test D, (See Fig. A-4) was accomplished.

Test P037-071 was successfully run on July 19, 1978, using the F2 Gimbal Program (See Fig. A-7).

Test P037-072 was conducted on July 19, 1978. This firing ran the 110 PCT APU speed performance requirement on tilt system, Test H, (See fig. A-10). No anomalies were detected.

Test P037-074 was successfully conducted on July 21, 1978, using the F2 Gimbal Program.

Test P037-075 was conducted on July 21, 1978. This test ran the 100 PCT APU speed performance requirements, Test E, (See Fig. A-5).

Test P037-076 was successfully run on July 24, 1978, using the E Gimbal Program again.

Test P037-077 was conducted on July 24, 1978. This firing ran the G Gimbal program, and no anomalies were detected.

Test P037-078 was conducted on July 24, 1978. This firing ran the D Gimbal Program, and it was cut at 152 seconds from low hydraulic fluid supply pressure on both APU's. The actuators lost the signal from the test computer because of a facility problem and were commanded to hard-over position (fully extended or retracted step command) prior to termination. It was also observed that the rock lube oil temperature had exceeded the redline value at cutoff time. No other anomalies were reported.

Test P037-079 was conducted on July 26, 1978. This hot firing ran the E Gimbal Program; but, the test was aborted by an underspeed cutoff signal on tilt APU that was activated early (2.9 seconds) because of instrumentation problem. The data indicates that the tilt APU GG pressure buildup was slow. Rock APU continued operating in the backup mode until 33.6 seconds when it was cut by low hydraulic fluid supply pressure caused by the high flow demand. (5 deg/sec gimbal rate in both actuators)

Test P037-080 was conducted on July 26, 1978. This hot firing ran the E gimbal program again. But, the test was aborted. Ancther underspeed cutoff signal this time at 3.7 seconds. The tilt APU GG and fuel pump outlet pressure buildup was slow, causing the slow start in the APU turbine speed. The test was cut manually at 11.9 seconds. Further analysis determined that this failure was caused by a leaking relief valve inside the fuel pump. The fuel pump was replaced prior to the next hot firing, and testing was resumed.

Test P037-081 was conducted on August 1, 1978, as a repeat of test P037-079. This time, the test lasted 160 seconds (full duration), and the only abnormal observation was the high lube oil temperature at the end of the test.

Test P037-082 was conducted on August 1, 1978. This hot firing ran the 110 PCT Rock APU Speed Performance Requirements, Test J, (See Fig. A-12) This firing was cut at 150.5 seconds because of high lube oil temperature. The gimbal program had just been completed with no further problems.

Test P037-083 was conducted on August 1, 1978, using the DM-3 Duty Cycle, Test N*, (See Fig. A-15). At test termination, the rock APU lube oil temperature was high. No other anomalies were reported during this test.

Test P037-084 was conducted on August 2, 1978, and this hot firing ran the Test D Gimbal Program.

Test P037-085 was successfully conducted on August 2, 1978, using the N* Gimbal Program.

Test P037-086 was conducted on August 2, 1978. This hot firing ran the Test E Gimbal Program, and no anomalies were detected.

Test P037-087 was conducted on August 3, 1978. This hot firing ran Test D Gimbal Program without any problems.

Test P037-088 was conducted on August 3, 1978. This hot firing ran Test D Gimbal Program. Rock APU experienced an early cutoff at 88.4 seconds due to high lube oil temperature. Further analysis and hardware inspection determined that this condition was created by an overfilled gearbox. This problem was caused by the inability of the rock gearbox optic level sensor to read the amount of oil in that gearbox. From this point onward level will be estimated by the temperature differential during a hot firing.

From August 7 to 22, 1978, the KSC Hot Firing Van was installed. and the TVC system hardware. facility. and test procedures were prepared to conform with that equipment.

Test P037-096 was conducted on August 28, 1978. This test ran the KSC checkout profile (C1 Gimbal Program). This run lasted 20 seconds, and no anomalies were reported.

Test P037-097 was conducted on August 29, 1978, using the D Gimbal Program. Vibration in the hydraulic line damaged some of the brackets that hold this line to the test frame. No other anomalies were reported. This test lasted 160 seconds.

Test P037-098 was conducted on August 30, 1978. The N* Gimbal Program was used. This run was aborted by the observer at 117 seconds because of high gas generator pressure (1750 psig). After checking out all the electronics, the conclusion was that the scale was erroneously set, and the actual pressure was (1325 psig). The TVC ran according to what was expected and no anomalies were reported in this test.

Test P037-099 was conducted on August 31, 1978, as a repeat of test P037-098. This time, the test was completed without any anomalies.

Test P037-100 was conducted on August 31, 1978. This firing ran APU Control Valve Redundancy Test, Test I, (See Fig. A-11). Some vibration was observed and some brackets became loose during this run which lasted 160 seconds, but no other anomalies were encountered.

Test P037-101 was successfully conducted on September 7, 1978, using the F3 Gimbal Program.

Test P037-102 was conducted on September 8, 1978, and this firing ran the D Gimbal Program. Vibration was still present, but no other problems were encountered.

Test P037-103 was successfully conducted on September 11, 1978, and the N* Gimbal Program was used.

Test P037-104 was conducted on September 11, 1978. This hot firing ran the I Gimbal Program. Vibration caused some brackets to get loose during this test, but no other anomalies were reported.

Test P037-105 was conducted on September 13, 1978. This firing ran the D Gimbal Program, but the vibration was still present in the system. No other problems were encountered.

Test P037-106 was successfully conducted on September 13, 1978, using the N* Gimbal Program.

Test P037-107 was conducted on September 15, 1978. This firing ran the D Gimbal Program. Vibration was still present, but no other problems were detected during this test. This was the last mission commanded from the KSC Hot Firing Van.

From September 15, to September 18, 1978, the KSC hot firing van was disconnected from the test stand, and instrumentation was changed to conform with the old facility (Block House).

Test P037-108 was conducted on September 19, 1978, using the D Gimbal Program. Vibration was still present, but no other anomalies were found.

Test P037-109 was conducted on September 27, 1978. This firing ran a special test to troubleshoot the vibration problem. The L Gimbal Program was used (See Figure A-13). The test lasted 113 seconds, and the vibration was still present.

Test P037-110 was conducted on October 6, 1978. This was a special test on hydraulic line vibration using the G Gimbal Program at 100 PCT APU speed for 160 seconds. No anomalies were observed during the test.

Test P037-111 was conducted on October 6, 1978. This was another special scheduled test on line vibration. The N* Gimbal Program was used, and vibration measurements were installed throughout the system prior to this run. No problems were encountered during the firing.

Test P037-112 was conducted on October 6, 1978. This was the 4th special run on vibration. The M Gimbal Program was used (see Figure A-14). The test lasted 146 seconds, and the vibration was still present.

Test P037-113 was conducted on October 6, 1978. This test ran the D Gimbal Program. Prior to this firing, the test frame was reinforced and new bracketry was added to the hydraulic lines to eliminate vibration. The problem disappeared after this run. This test lasted 160 seconds, and no other anomalies were present.

Test P037-114 was conducted on October 16, 1978. This test ran the F3 Gimbal Program (see Figure A-8). But, the test was aborted by the test conductor when the tilt actuator failed to move to the command signals. After visual inspection at the test site, it was determined that the tilt actuator prefiltration valve was left open prior to the hot firing. After the system's inspection and data analysis were made, it was resolved that there was no hardware damage, and that no redlines were exceeded.

Test P037-115 was conducted on October 16, 1978, as a repeat of test P037-114. This time, TVC ran successfully for 160 seconds.

Test P037-116 was conducted on October 17, 1978, using the D Gimbal Program.

Test P037-117 was successfully conducted on October 18, 1978, using the E Gimbal Program.

Test P037-118 was conducted on October 19, 1978. This firing ran the D Gimbal Program. No anomalies were reported.

Test P037-119 was conducted on October 20, 1978. This firing ran the H Gimbal Program, and no problems were encountered.

Test P037-120 was conducted on October 23, 1978, and this firing employed the D Gimbal Program.

Test P037-121 was conducted on October 24, 1978. This firing ran the D Gimbal Program again. No anomalies were reported.

Test P037-122 was conducted on October 25, 1978, using the E Gimbal Program. A fluid leak inside the tilt hydraulic reservoir resulted in the accumulation of 2000 cc of oil in the air side cavity (bottom side of piston) during the past few tests. No other anomalies were found.

Test P037-123 was conducted on October 26, 1978, and this firing ran the I Gimbal Program. The amount of fluid leaking inside the tilt hydraulic reservoir was 5-10 cc during this test. No other problems were reported.

Test P037-124 was conducted on October 27, 1978. This firing ran the E Gimbal Program. During a past test inspection, 500 cc of fluid was discovered in the air side cavity of the hydraulic reservoir. After a thorough investigation, it was decided to replace this hardware and send it to the vendor for repair.

Test P037-158 was conducted on March 26, 1979. This firing ran the D Gimbal Program. No problems were encountered.

Test P037-159 was successfully conducted on March 29, 1979, using the D Gimbal Program again.

Test P037-160 was conducted on March 30, 1979. This firing ran the C2 Gimbal Program (See Fig. A-3) 4 times. No anomalies were reported.

Test P037-161 was conducted on March 30, 1979. This firing ran the C2 Gimbal Program 3 times. No problems were found.

Test P037-162 was conducted on April 2, 1979, and this firing ran the J Gimbal Program.

Test P037-163 was successfully conducted on April 3, 1979, using the E Gimbal Program.

Test P037-164 was conducted on April 4, 1979. This firing ran the G Gimbal Program and simulated the fuel cell switching transient. Power was removed from the rock APU for 100 ms at 100, 110, 112 PCT turbine speed during gimbaling. No problems were encountered.

Test P037-165 was conducted on April 10, 1979. This firing repeated Test P037-164; although, this time, power was removed from the tilt APU. This firing was a success.

Test P037-166 was successfully conducted on April 10, 1979, using the F1 Gimbal Program. The data from this test will be compared with test P037-067 to correlate trends and system degradation. No anomalies were found in the systems during the firing.

Test P037-167 was conducted on April 11, 1979. This test ran the G Gimbal Program without any problems. The data from this test will be compared with test P037-069 to correlate trends and system degradation. This was the last hot firing during V-2 testing.

Description

A. Auxiliary Power Unit (APU)

The operation of both auxiliary power units during V-2 testing was excellent. Both APU's were subjected to 66 starts and performed flawlessly to all the loads that were imposed. This could be seen in the data coming off parameters like: turbine speed, fuel pump outlet and gas generator pressures, and the time the control valves stayed open. Two of the major problems: the leaking control valves and the fuel pump leaking relief valve were caused by contaminants introduced into the system during servicing. The other problem was the gearbox broken diaphragm which was not a test constraint although it made it difficult to read the lube oil level.

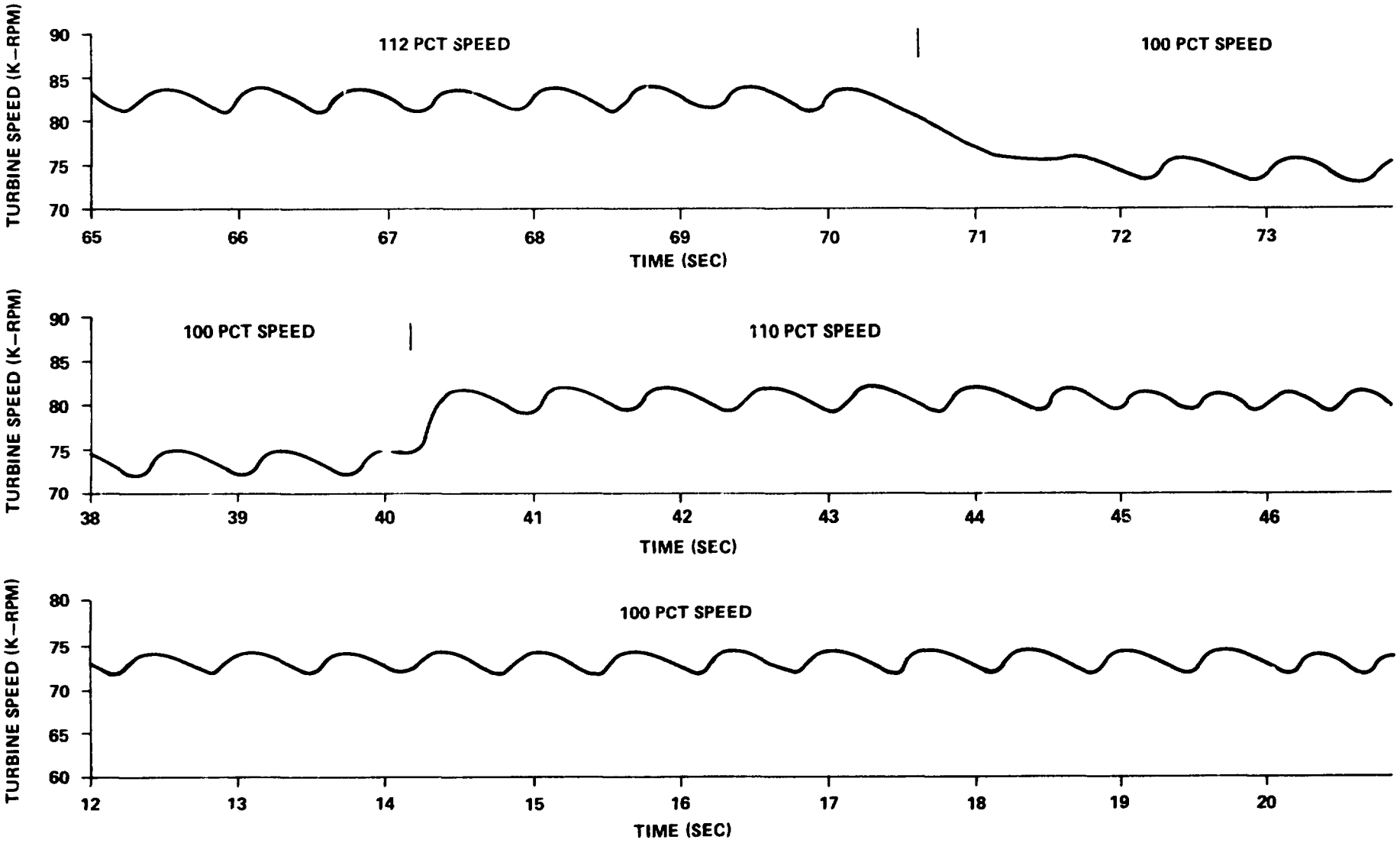
The APU turbine speed cycled within the expected band: -4.2 PCT to + 3.5 PCT for rock APU; and - 5.3 PCT to + 4.3 PCT for tilt. This was obtained at a 5 deg/sec actuator gimbal rate. The average transient startup period necessary to obtain rated speed is 3.13 seconds for rock APU and 3.26 seconds for tilt. This transient time was achieved with an average gas generator bed temperature of 225° F at start. Figures 2 and 3 show the turbine speed at 100 PCT, 110 PCT, and 112 PCT for both APU's. Figures 4 and 5 show the start transient speed in test P037-167 for both APU's. Figure 6 shows the turbine speed transient when the actuators are commanded to a 5 deg/sec gimbal rate.

The average time the gas generator control valves are open was: 110-130 ms for rock; and 130-150 ms for tilt. The valves were opened for a longer period of time at a 5 deg/sec gimbal rate, but this amount of time depends on how long the actuators were gimbaled at this rate. The fuel

pump pressure was: 1300 to 1350 psig for rock APU; and 1400 to 1450 psig for tilt. (This occurring at 100 PCT turbine speed). The gas generator pressure was: 1100 to 1150 psig for rock and 1200 to 1250 psig for tilt. All these measurements show the good performance of the APU's throughout the different runs. Figures 7 through 12 show the gas generator and fuel pump outlet pressures at: 100 PCT; 110 PCT, and 112 PCT turbine speed.

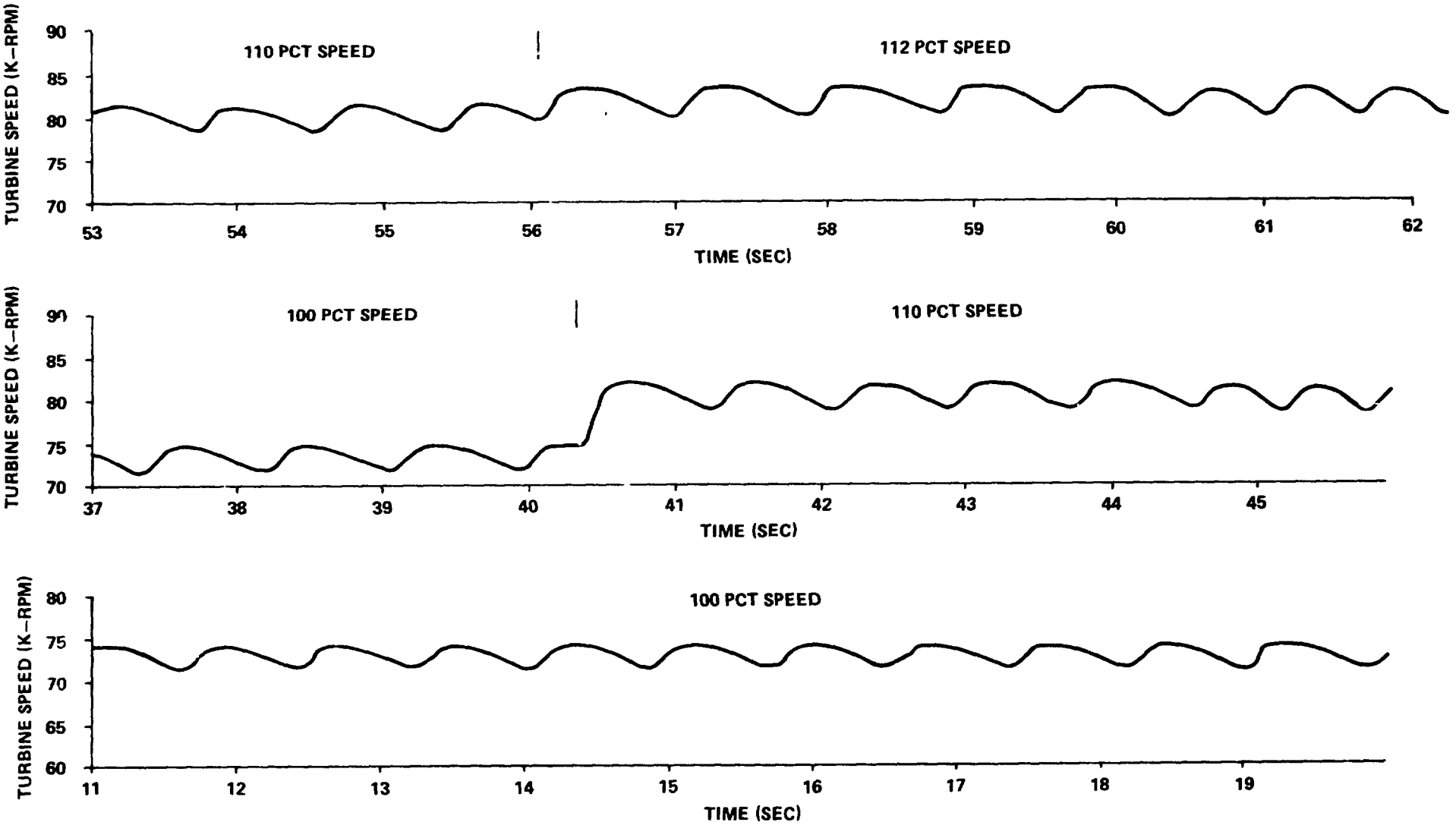
For most full duration hot firings, the gas generator maximum bed temperature range from 1100° F to 1200° F and the turbine exhaust temperature from 450° F to 600° F. The temperature variations are normally a function of the gimbal program and of the turbine speed. For more information, see Table 7.

The lube oil and the gearbox were the areas of concern during verification testing. One hot firing (test P037-088) was aborted due to high lube oil temperature caused by an overfilled gearbox in the rock system. The lube oil level in the gearbox can be detected by the optic sensors However, this measurement does not verify the total lube oil volume. Therefore, lube oil temperature rise must be considered. Flight APU's are provided with the capability of indicating actual gearbox lube oil volumes. The normal temperature rise for a full duration hot firing ranges from 100°F to 140°F (see Table 8).



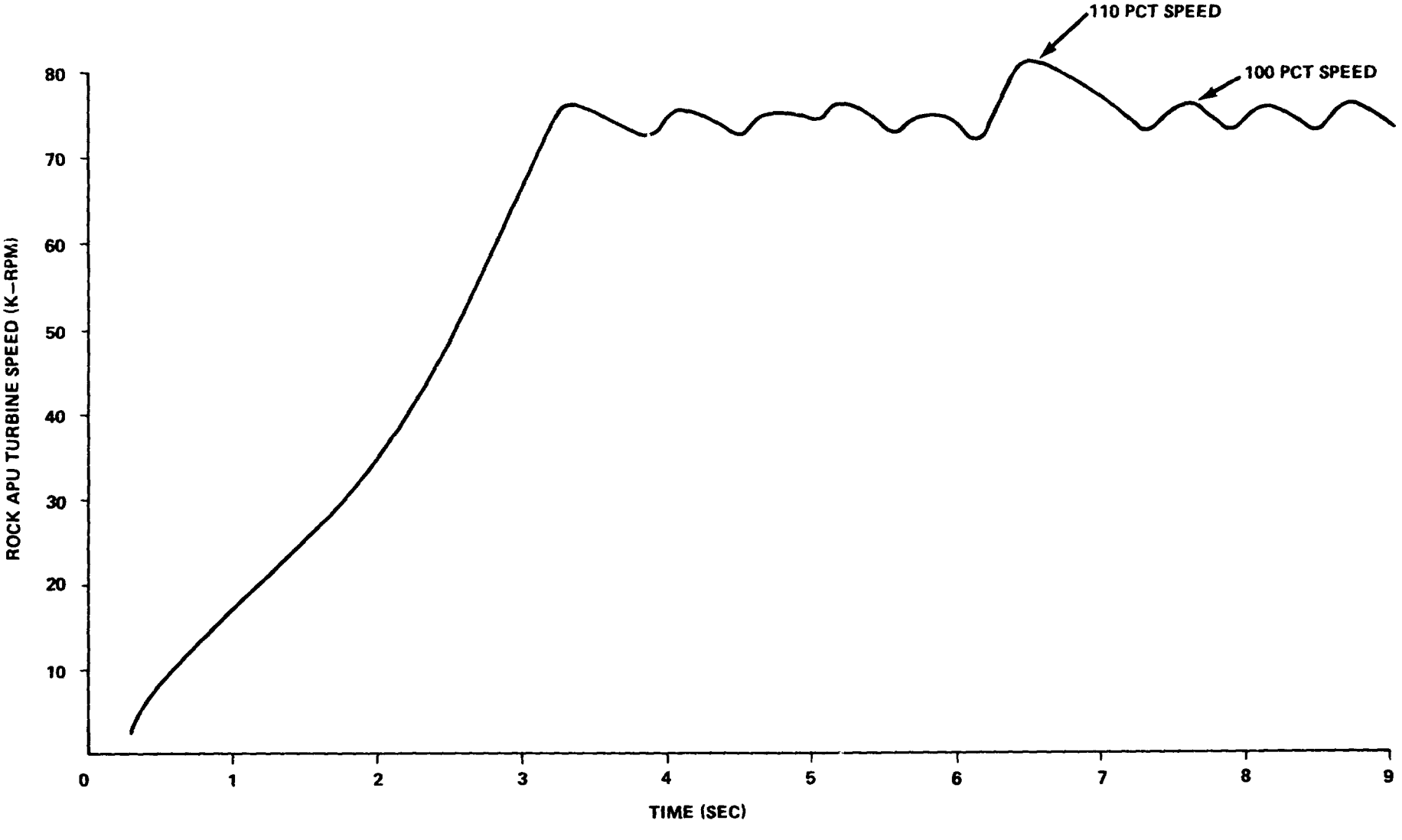
ROCK APU TURBINE SPEED TRANSIENT FOR TEST P037–167

FIGURE 2



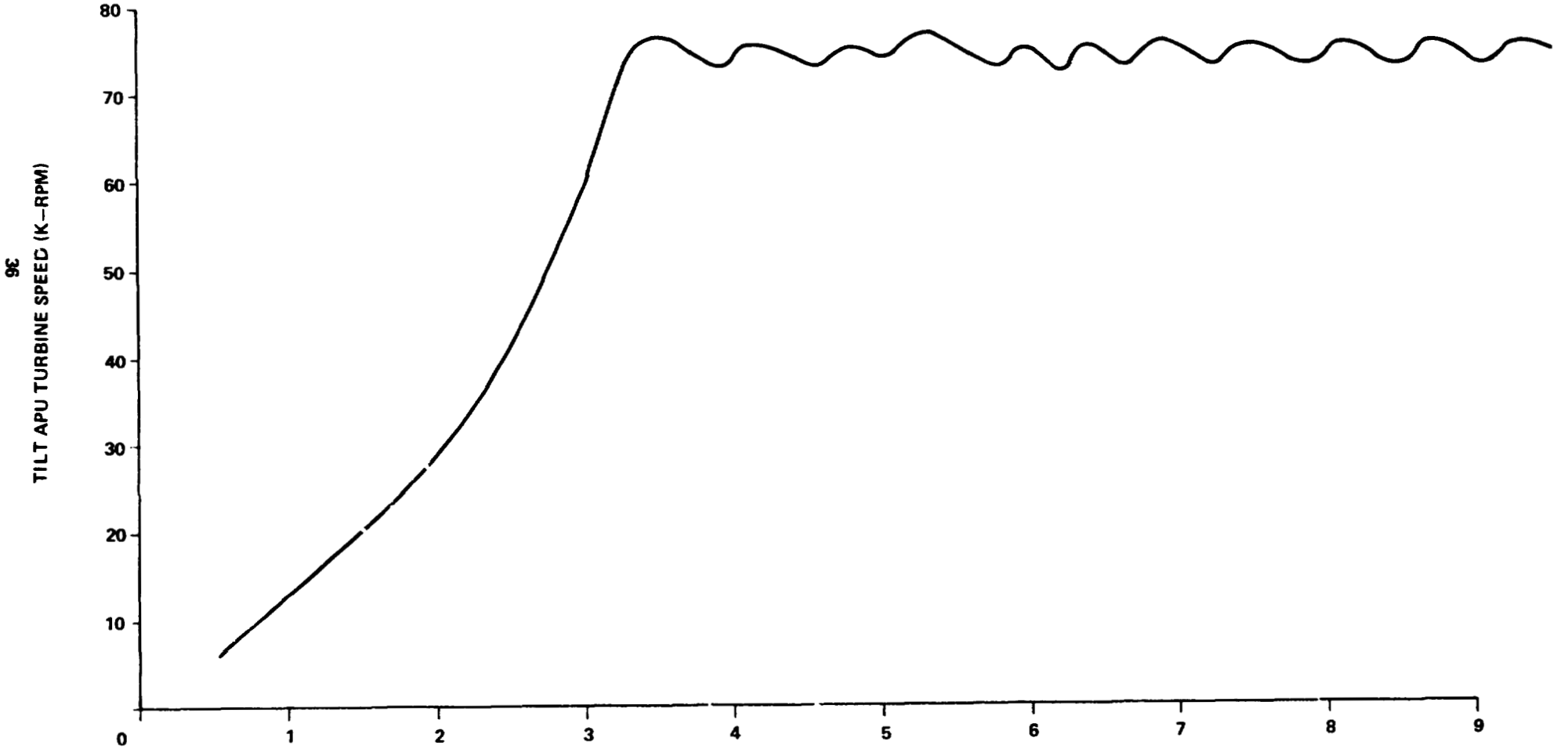
TILT APU TURBINE SPEED TRANSIENT FOR TEST P037-167

FIGURE 3



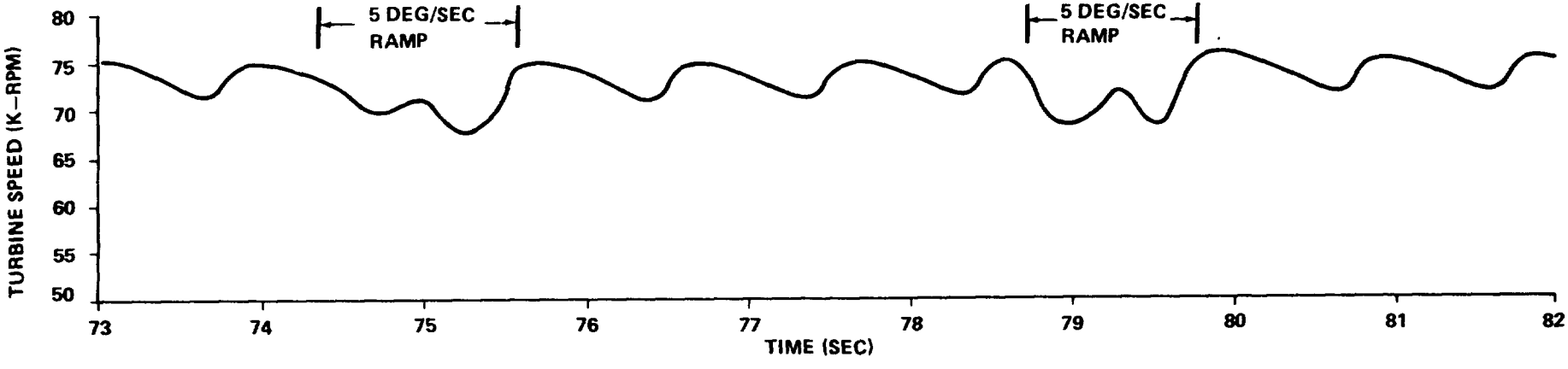
ROCK APU TURBINE SPEED START TRANSIENT

FIGURE 4



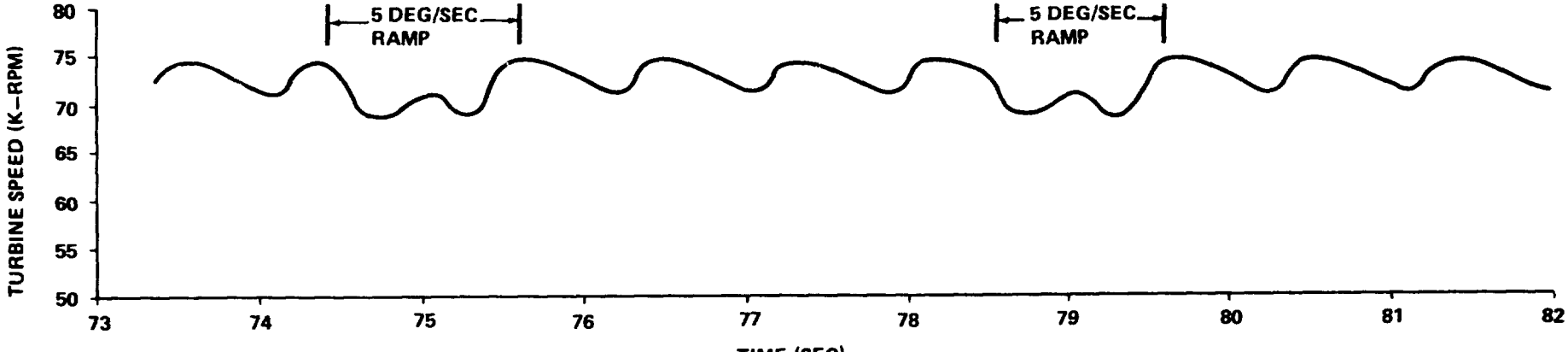
TILT APU TURBINE SPEED START TRANSIENT

FIGURE 5



TILT APU TURBINE SPEED TRANSIENT AT 5 DEG/SEC ACTUATOR GIMBAL RATE

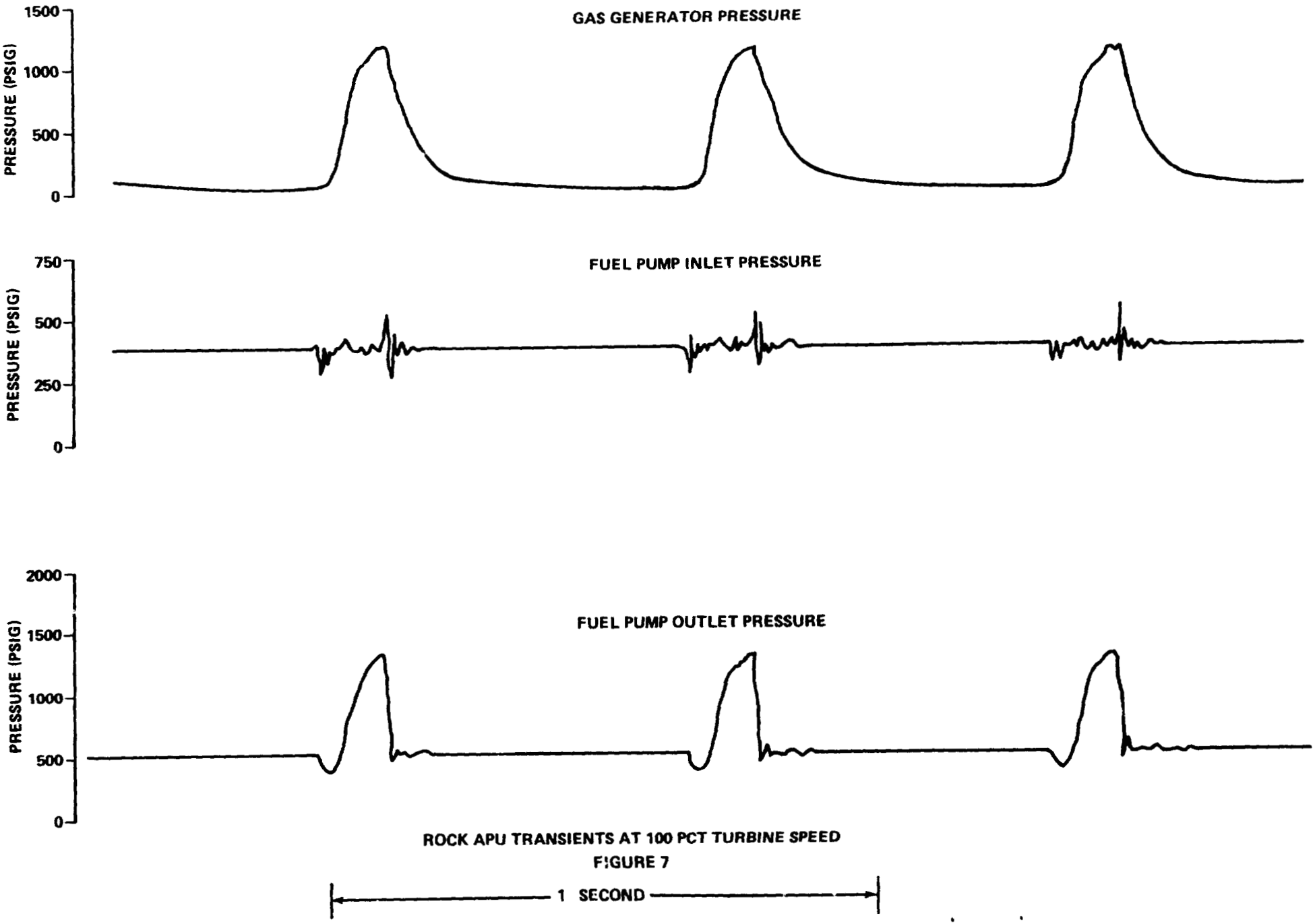
(TEST P037–165)



ROCK APU TURBINE SPEED TRANSIENT AT 5 DEG/SEC ACTUATOR GIMBAL RATE

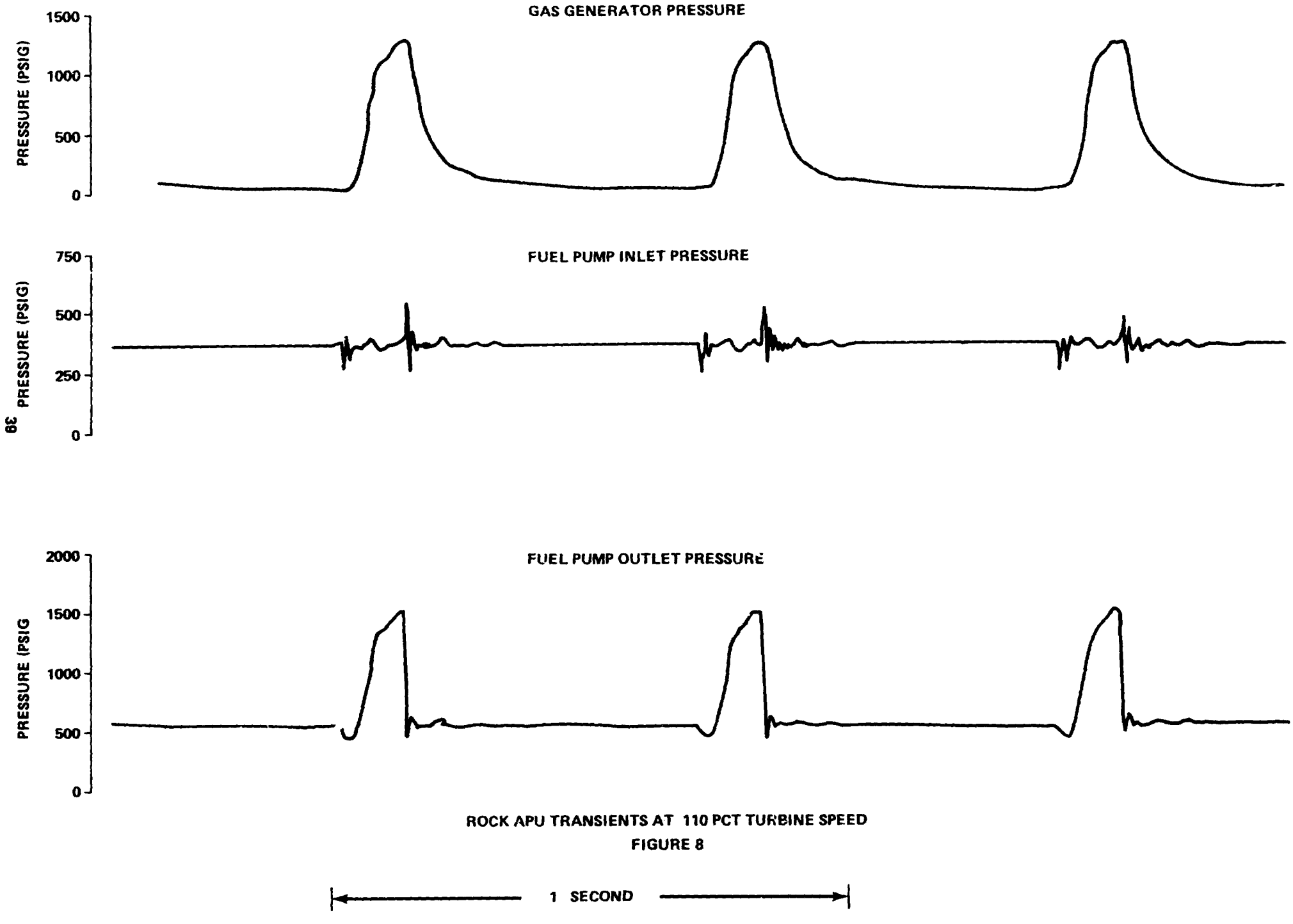
(TEST P037–165)

FIGURE 6



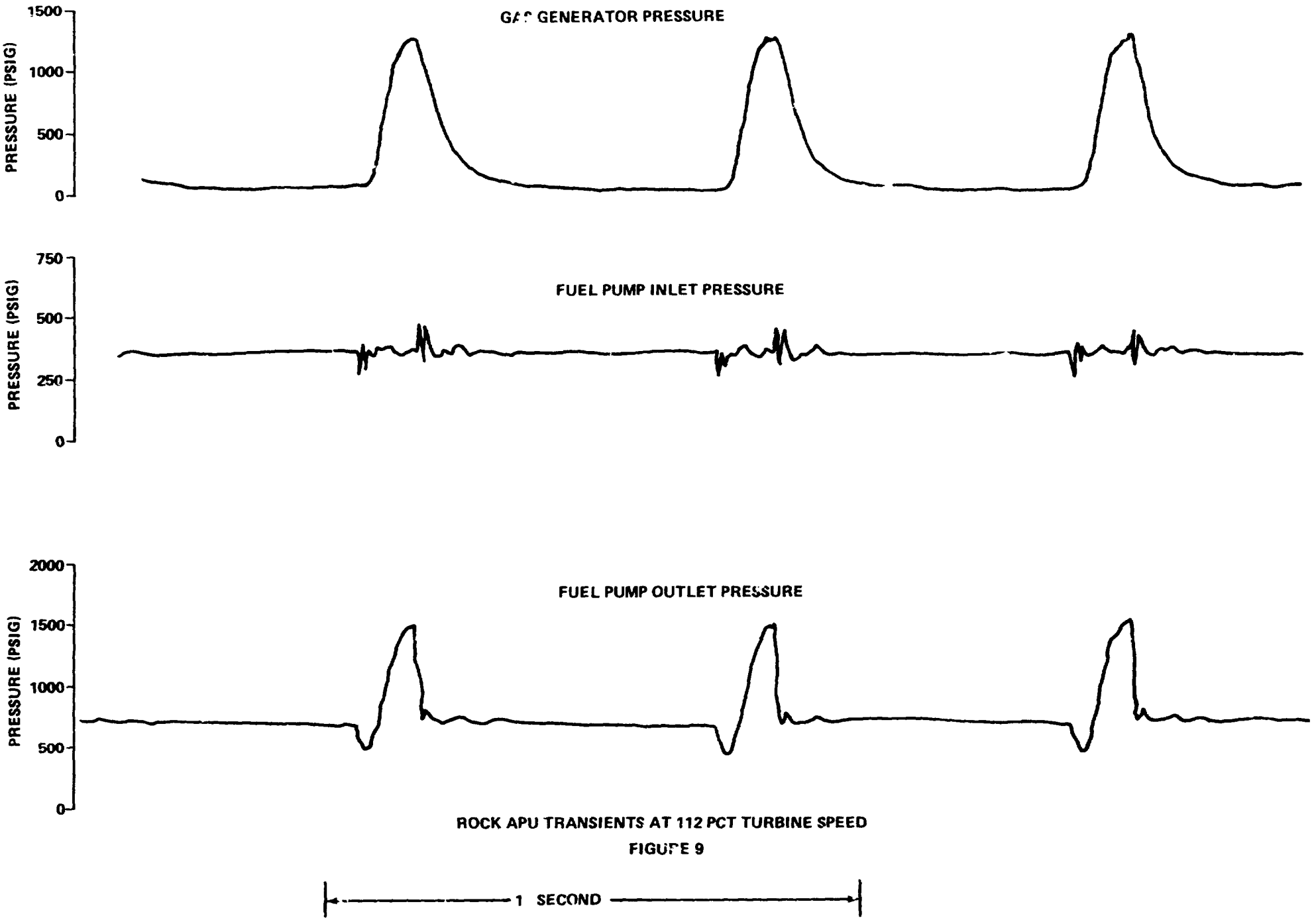
ROCK APU TRANSIENTS AT 100 PCT TURBINE SPEED

FIGURE 7



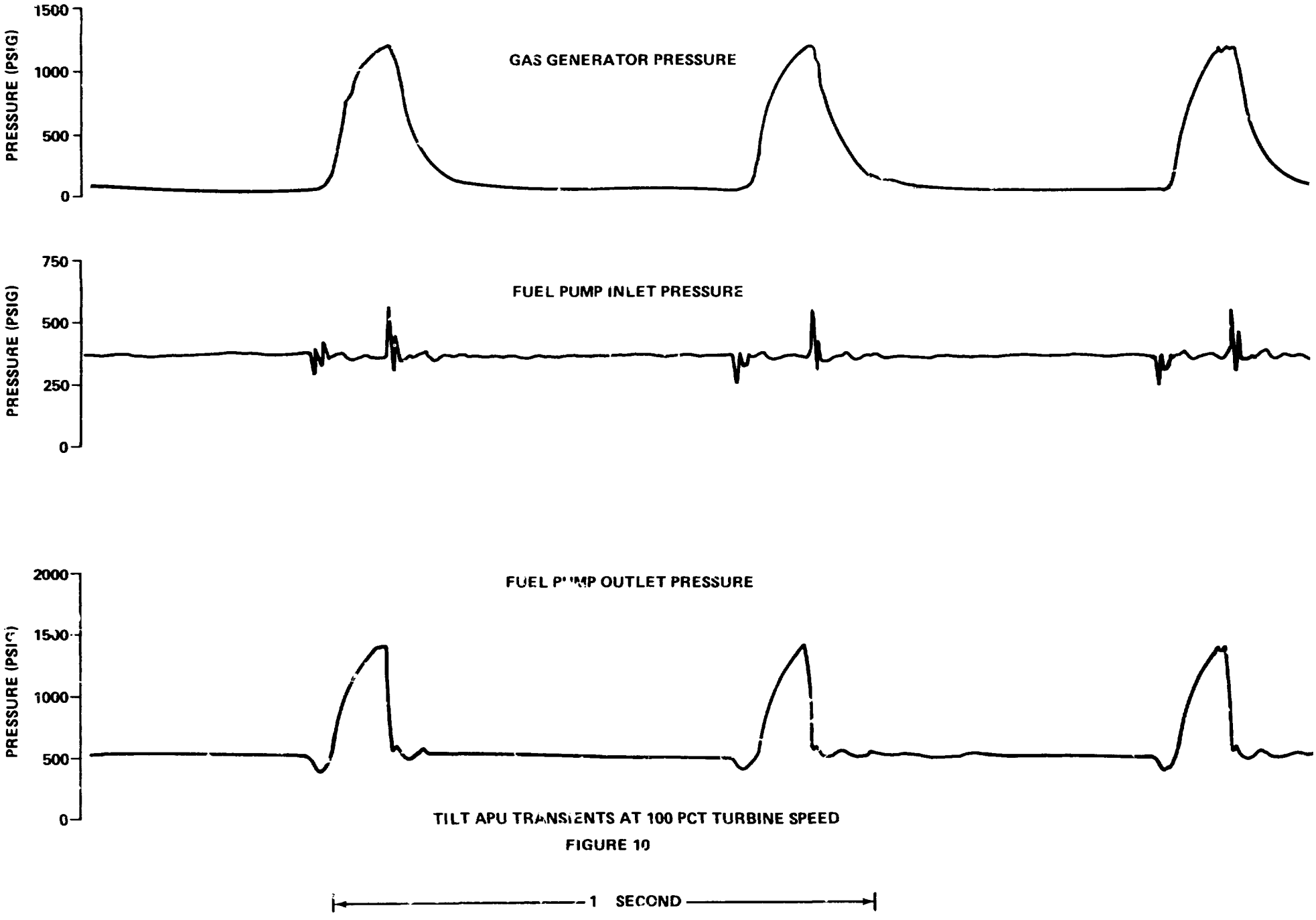
ROCK APU TRANSIENTS AT 110 PCT TURBINE SPEED

FIGURE 8



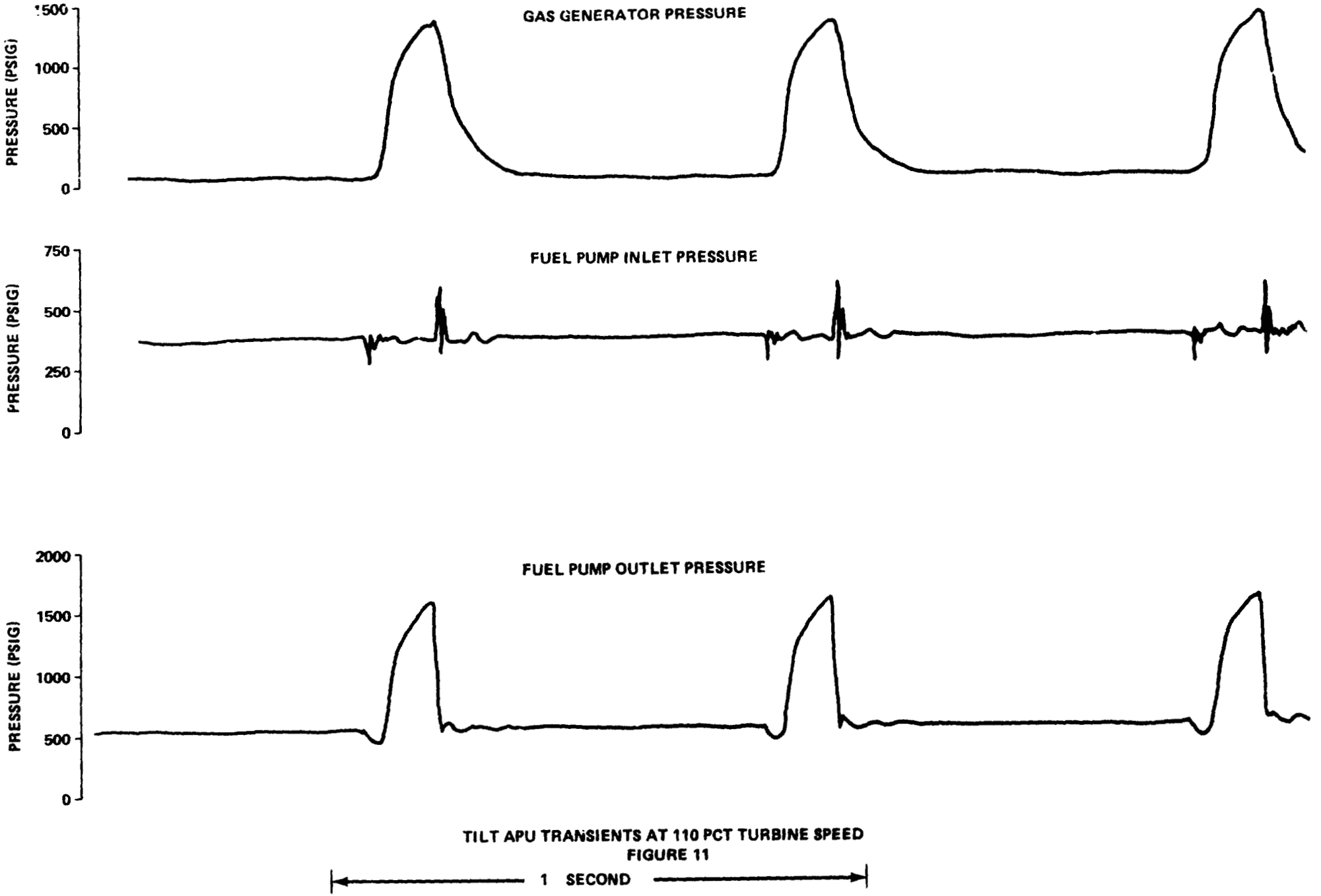
ROCK APU TRANSIENTS AT 112 PCT TURBINE SPEED

FIGURE 9

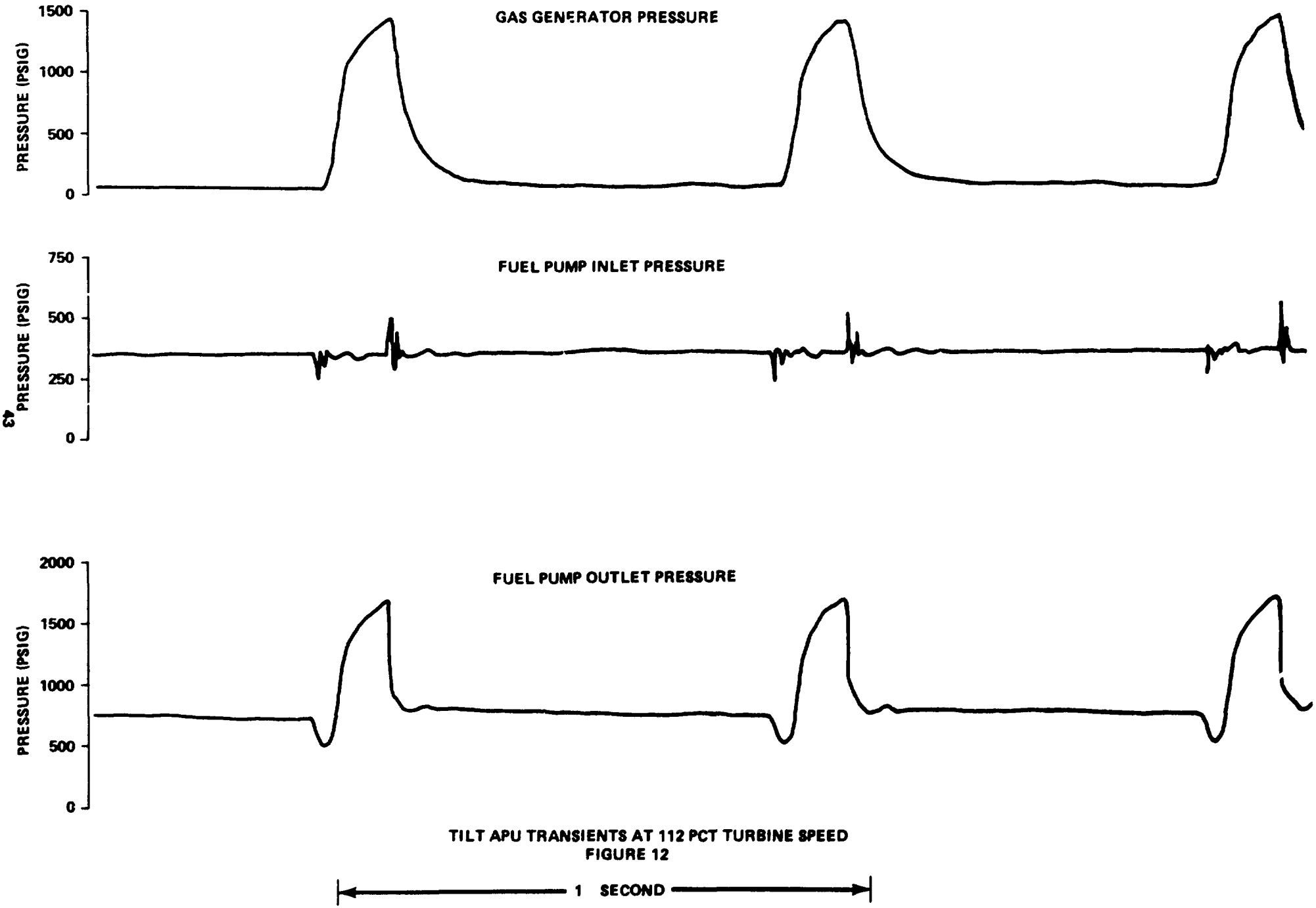


TILT APU TRANSIENTS AT 100 PCT TURBINE SPEED

FIGURE 10



TILT APU TRANSIENTS AT 110 PCT TURBINE SPEED
FIGURE 11



TILT APU TRANSIENTS AT 112 PCT TURBINE SPEED
FIGURE 12

TABLE 7

AUXILIARY POWER UNIT TEMPERATURE

		ROCK SYSTEM						TILT SYSTEM					
		GAS GENERATOR TEMPERATURE (°F)			TURBINE EXHAUST TEMPERATURE (°F)			GAS GENERATOR TEMPERATURE (°F)			TURBINE EXHAUST TEMPERATURE (°F)		
		START	MAX	END	START	MAX	END	START	MAX	END	START	MAX	END
P037	– 024	–	–	–	41	186	186	–	–	–	41	183	183
	– 025	202	1014	1014	44	441	441	214	985	985	57	458	458
	– 026	215	1172	1161	63	570	542	235	1118	1116	84	564	564
	– 062	221	475	475	86	198	198	212	443	443	84	192	192
	– 066	214	214	214	92	130	130	200	596	596	87	291	291
	– 067	222	1122	1122	90	553	546	208	1087	1085	88	519	507
	– 068	200	1048	1048	89	493	488	216	244	244	87	183	183
	– 069	219	1110	1110	89	537	533	200	1067	1067	87	501	501
	– 070	209	1143	1137	92	567	563	220	1111	1107	92	552	543
	– 071	207	1147	1143	89	575	567	216	1118	1112	85	556	544
	– 072	212	491	491	97	217	217	209	1193	1175	96	627	609
	– 074	208	1151	1146	91	577	568	200	1122	1118	88	566	553
	– 075	206	1151	1143	94	569	566	221	1117	1112	92	553	545
	– 076	221	1159	1149	92	571	563	204	1122	1114	87	559	550
	– 077	198	1112	1112	93	554	553	205	1083	1083	92	515	511
	– 078	235	1188	1188	95	646	646	230	1125	1123	94	586	586
	– 079	208	779	779	87	441	441	223	225	225	82	132	132
	– 080	204	354	354	91	196	196	205	210	210	90	163	163
	– 081	222	1173	1170	85	588	586	214	1131	1124	83	553	549
	– 082	200	1239	1232	90	675	657	211	521	521	87	218	214
	– 083	219	1157	1157	90	598	577	210	1124	1124	89	583	545
	– 084	205	1157	1155	90	588	588	207	1125	1120	89	553	543
	– 085	209	1130	1130	94	578	547	206	1119	1118	93	579	531
	– 086	215	1149	1143	95	577	569	216	1126	1120	94	569	566
	– 087	219	1149	1144	92	578	577	206	1126	1120	89	557	551
	– 088	221	1151	1151	94	586	586	218	1179	1169	93	611	603
	– 096	255	630	630	110	255	255	240	610	610	110	280	280

TABLE 7

AUXILIARY POWER UNIT TEMPERATURE (CONT'D)

TEST NUMBER		ROCK SYSTEM						TILT SYSTEM					
		GAS GENERATOR TEMPERATURE (°F)			TURBINE EXHAUST TEMPERATURE (°F)			GAS GENERATOR TEMPERATURE (°F)			TURBINE EXHAUST TEMPERATURE (°F)		
		START	MAX	END	START	MAX	END	START	MAX	END	START	MAX	END
P037	– 097	230	1180	1170	110	640	620	250	1180	1180	110	645	640
	– 098	240	1130	1130	90	525	525	255	1140	1140	90	585	585
	– 099	255	1180	1180	100	650	600	250	1170	1170	90	680	640
	– 100	250	1215	1210	90	650	650	255	1200	1200	90	670	670
	– 101	255	1190	1190	100	645	600	255	1190	1180	110	675	640
	– 102	270	1200	1200	100	640	630	250	1190	1170	90	645	630
	– 103	255	1190	1190	105	660	610	260	1190	1190	110	690	645
	– 104	255	1210	1210	100	670	670	260	1200	1200	110	680	680
	– 105	255	1200	1190	100	640	630	240	1190	1180	105	660	640
	– 106	255	1180	1180	90	650	600	255	1180	1180	100	690	645
	– 107	260	1185	1170	90	610	600	270	180	1170	100	660	640
	– 108	216	1158	1151	96	589	586	225	1137	1131	95	567	563
	– 109	225	1119	1119	72	543	529	201	1079	1079	72	499	478
	– 110	223	1117	1117	54	552	550	202	1086	1086	55	512	510
	– 111	219	1137	1137	62	599	569	206	1118	1118	60	604	562
	– 112	223	1111	1111	64	543	540	206	1087	1087	63	530	518
	– 113	224	1162	1156	67	592	587	202	1127	1123	66	583	574
	– 114	224	1182	1182	–	–	–	–	–	–	–	–	–
	– 115	254	1120	1114	–	–	–	252	1066	1066	–	–	–
	– 116	225	1142	1134	56	577	571	202	1126	1123	55	553	550
	– 117	224	1140	1129	61	580	570	204	1127	1120	58	565	556
	– 118	226	1151	1142	66	588	582	216	1120	1116	65	579	566
	– 119	237	505	505	65	191	191	199	1185	1175	62	667	655
	– 120	227	1150	1142	73	593	590	213	1129	1122	71	591	583
	– 121	227	1137	1130	58	583	579	198	1118	1114	53	562	554
	– 122	222	1148	1134	69	587	581	203	1123	1117	64	579	568
	– 123	226	1170	1163	72	600	600	217	1143	1141	70	595	591

TABLE 7

AUXILIARY POWER UNIT TEMPERATURE (CONT'D)

TEST NUMBER	ROCK SYSTEM						TILT SYSTEM					
	GAS GENERATOR TEMPERATURE (°F)			TURBINE EXHAUST TEMPERATURE (°F)			GAS GENERATOR* TEMPERATURE (°F)			TURBINE EXHAUST TEMPERATURE (°F)		
	START	MAX	END	START	MAX	END	START	MAX	END	START	MAX	END
P037 – 124	224	1147	1134	60	580	573	205	1119	1115	58	558	544
– 131	180	1067	1065	44	547	529	210	1085	1079	38	512	466
– 158	216	1137	1132	56	591	585	223	943	847	54	555	543
– 159	213	1137	1132	82	586	582	231	897	833	80	561	549
– 160	217	980	980	80	457	454	224	846	843	78	341	337
– 161	299	934	934	77	439	436	298	827	827	73	305	304
– 162	222	1221	1195	66	662	638	220	520	520	65	185	183
– 163	211	1146	1132	62	584	571	231	924	903	61	558	545
– 164	227	1112	1112	67	557	557	231	911	907	65	507	500
– 165	230	1106	1102	58	549	549	228	942	938	56	502	500
– 166	232	1124	1120	67	577	560	229	962	957	64	556	530
– 167	227	1113	1111	83	554	550	231	986	982	81	518	513

*STARTING WITH TEST P037–158, TRANSDUCER READING WAS BAD DUE TO A LOOSE CONNECTION

TABLE 8

LUBE OIL TEMPERATURE

TEST NUMBER	ROCK SYSTEM				TILT SYSTEM			
	T6A		T6A AUX		T6B		T6B AUX	
	START	END	START	END	START	END	START	END
P037 – 024	45	50	45	68	45	51	42	55
– 025	72	128	65	147	63	133	65	137
– 026	69	169	64	185	73	188	71	183
– 062	97	105	91	118	96	106	97	115
– 066	100	101	96	102	102	116	98	126
– 067	90	204	90	204	88	199	93	190
– 068	96	162	89	173	97	98	100	106
– 069	85	204	82	206	83	199	85	198
– 070	95	210	90	211	93	202	95	200
– 071	88	203	86	205	85	193	83	174
– 072	99	112	95	112	98	218	95	186
– 074	88	201	87	202	86	194	85	171
– 075	95	206	91	203	95	205	99	193
– 076	88	203	88	204	86	194	91	182
– 077	99	216	94	216	97	209	97	202
– 078	113	288	103	310	111	215	106	204
– 079	85	107	81	121	84	84	99	97
– 080	94	96	88	98	88	88	91	93
– 081	84	240	82	256	82	196	85	171
– 082	93	288	87	310	91	102	90	107
– 083	99	252	93	269	93	211	94	184
– 084	89	211	89	219	87	197	90	186
– 085	97	205	94	207	95	206	96	181
– 086	102	211	98	213	101	211	101	184

TABLE 8

LUBE OIL TEMPERATURE (CONT.)

	ROCK SYSTEM				TILT SYSTEM			
	T6A		T6A AUX		T6B		T6B AUX	
TEST NUMBER	START	END	START	END	START	END	START	END
P037 – 087	88	201	85	205	87	194	86	184
– 088	99	289	94	310	97	212	92	181
– 096	96	104	92	115	96	102	94	113
– 097	94	198	86	199	84	202	87	213
– 098	88	174	85	175	88	162	86	172
– 099	82	200	78	199	84	190	79	193
– 100	102	226	88	230	102	234	90	248
– 101	90	202	85	200	92	196	89	199
– 102	82	192	76	197	80	184	77	197
– 103	94	202	88	202	94	194	92	203
– 104	112	230	105	232	112	228	105	245
– 105	90	194	92	200	92	190	94	204
– 106	88	198	82	199	88	192	83	195
– 107	78	182	76	182	80	184	76	190
– 108	97	201	92	201	94	187	95	190
– 109	73	154	68	162	72	144	71	158
– 110	57	181	52	183	55	170	54	177
– 111	85	207	70	209	81	196	70	201
– 112	79	189	69	192	77	178	71	183
– 113	80	203	71	203	78	191	72	194
– 114	61	133	59	143	59	128	59	141
– 115	75	196	66	192	75	182	68	187
– 116	55	174	52	175	53	158	52	173
– 117	60	179	54	177	56	163	55	174

TABLE 8

LUBE OIL TEMPERATURE (CONT.)

	ROCK SYSTEM				TILT SYSTEM			
	T6A		T6A AUX		T6B		T6B AUX	
TEST NUMBER	START	END	START	END	START	END	START	END
P037 – 118	63	182	60	181	62	180	63	195
– 119	62	67	59	76	69	190	74	195
– 120	69	185	66	185	68	180	66	189
– 121	59	180	56	182	56	167	57	179
– 122	63	184	60	180	60	170	60	181
– 123	72	207	71	206	70	195	71	201
– 124	58	182	51	185	56	165	52	175
– 131	68	184	62	184	64	179	60	185
– 158	57	192	55	201	55	167	55	176
– 159	81	193	78	196	79	187	79	196
– 160	79	138	75	150	77	132	74	148
– 161	99	147	88	158	95	141	87	154
– 162	67	200	66	209	64	71	64	84
– 163	63	168	62	170	60	169	60	180
– 164	67	185	65	185	66	178	66	182
– 165	56	171	54	176	54	170	54	179
– 166	76	165	67	168	72	179	66	194
– 167	81	175	78	173	79	188	78	200

B. Hydraulic Components

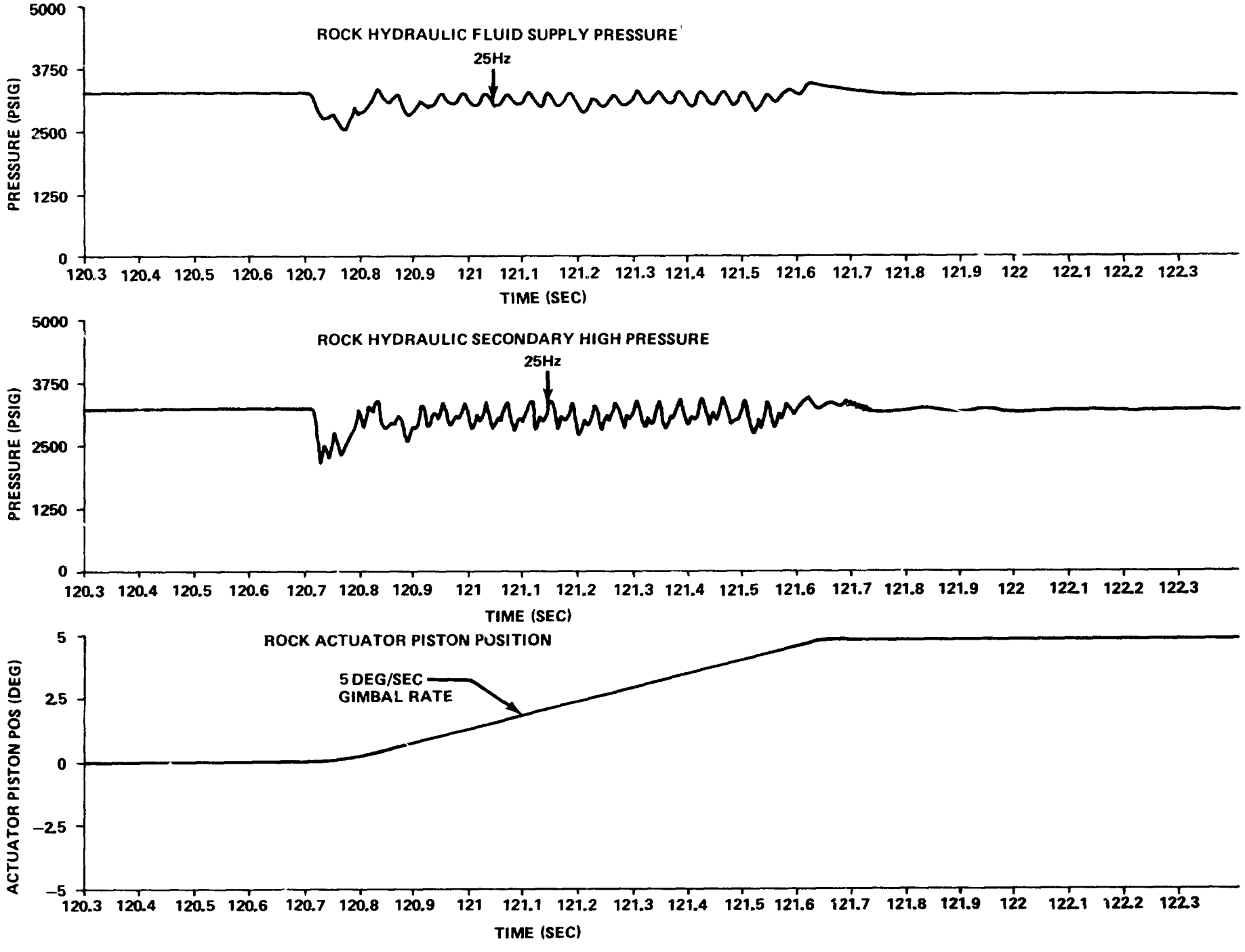
During V-2 hot firing operations, the behavior of the hydraulic components: pumps, reservoirs, manifolds, filters and actuators was excellent in most cases with a few scattered problems. The main problems encountered during hot firing operations were: a hydraulic fluid leak developed in the tilt reservoir which was sent back to the vendor for repairs, and a minor leak in the tilt pump shaft seal which was not considered important. Another problem was the two reservoir Tops that were blown out as a result of procedural error in the hydraulic fill, flush, and bleed operation. This was not a system's failure.

The system was exposed to a series of gimbal programs with a combination of ramps, step commands and sine waves (see Figures A-1 through A-16). and the behavior of the different hydraulic pressures was observed.

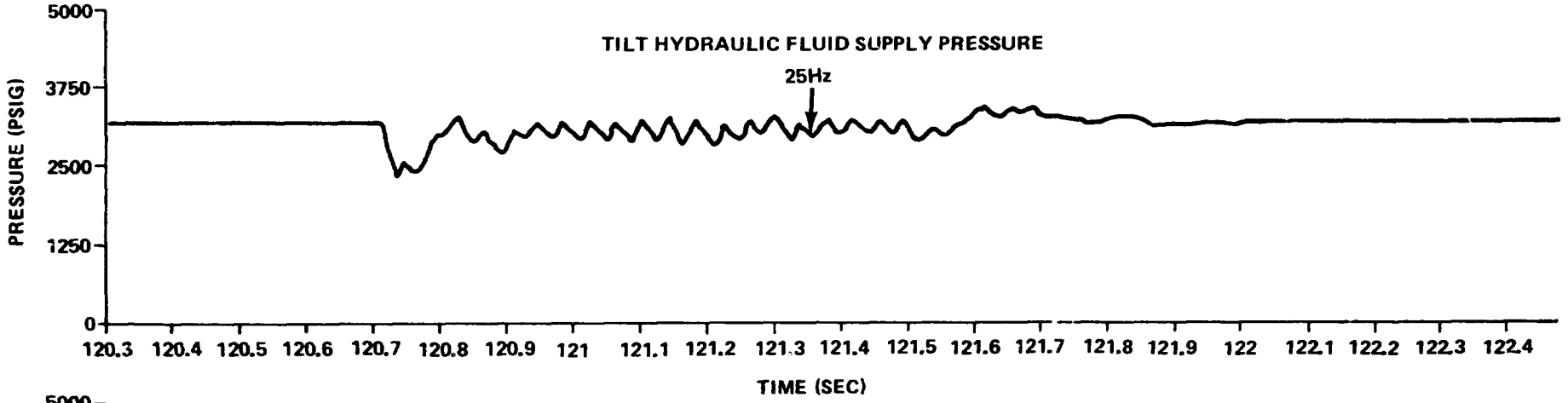
The hydraulic pump maintained a high pressure under all types of gimbal rates that the actuator was commanded to during these tests. The pressure surges resulting from servovalve operation as the actuators were gimbaled was studied. The hydraulic fluid supply pressure (primary high pressure) in both systems was maintained over 3000 psig through most of gimbal program. It rarely dropped below 2500 psig, and when it did, it was for just a few milliseconds (see Figures 13 through 16). The worse drops occurred during the frequency response (sine wave input) at 4 and 6 Hz where the pressure dipped to 1750 psig in rock system and 1500 psig in tilt, again for just a few milliseconds. (See Figures D-1 through D-18).

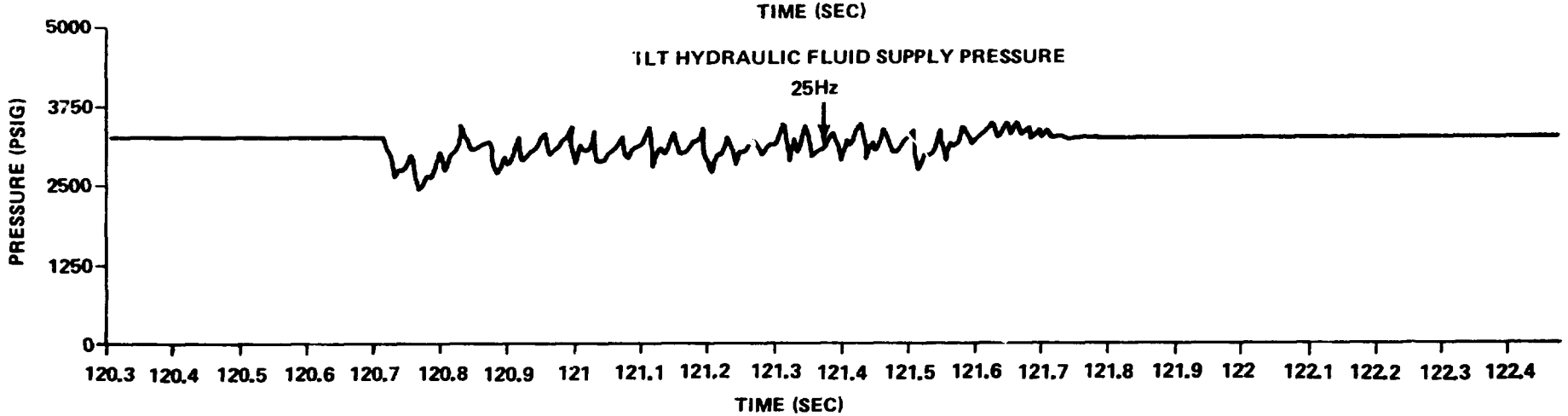
These oscillation modes can be seen when the actuators are gimbaled: 12 Hz, 25 Hz, and 60 Hz. The 12 Hz and 60 Hz are the hydraulic pump oscillation modes (see Figures 15 and 16). The 25 Hz is caused by a ramp command signal which is 25 steps per second (see Figures 13 and 14).

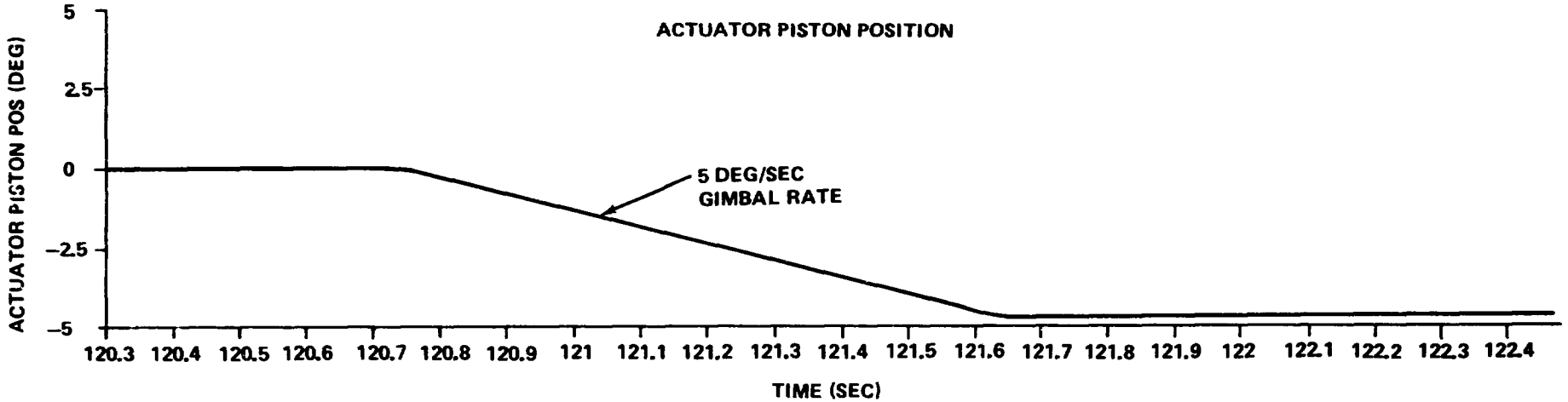
The hydraulic fluid temperature rise never presented any problems. The usual increase in Temperature was 20°F to 30°F although in some test, the rise was close to 40°F, but this was due to the gimbal rogram imposed on the system. The reservoir level never exceeded 80 PCT during hot firing operations and was never near being filled. (See Table 9) The hydraulic manifold low pressure showed unusually high surges (up to 500 psig in some cases, but just for 5-10 ms only). This was never reflected in the reservoir pressure parameter since it never exceeded 90 psig in a given test.



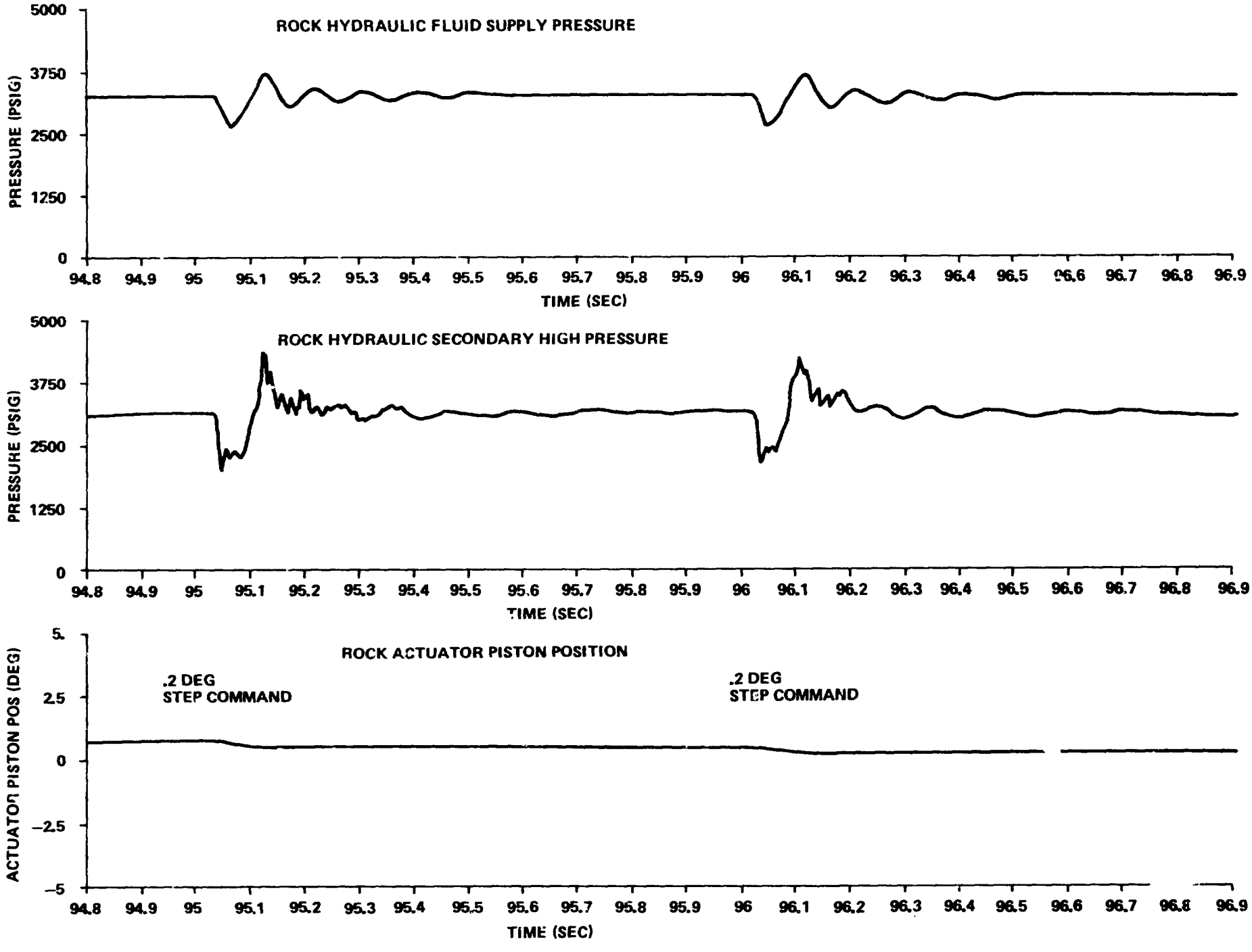
ROCK HYDRAULIC HIGH PRESSURE TRANSIENT AT 5 DEG/SEC RAMP
(TEST P037–131)
FIGURE 13



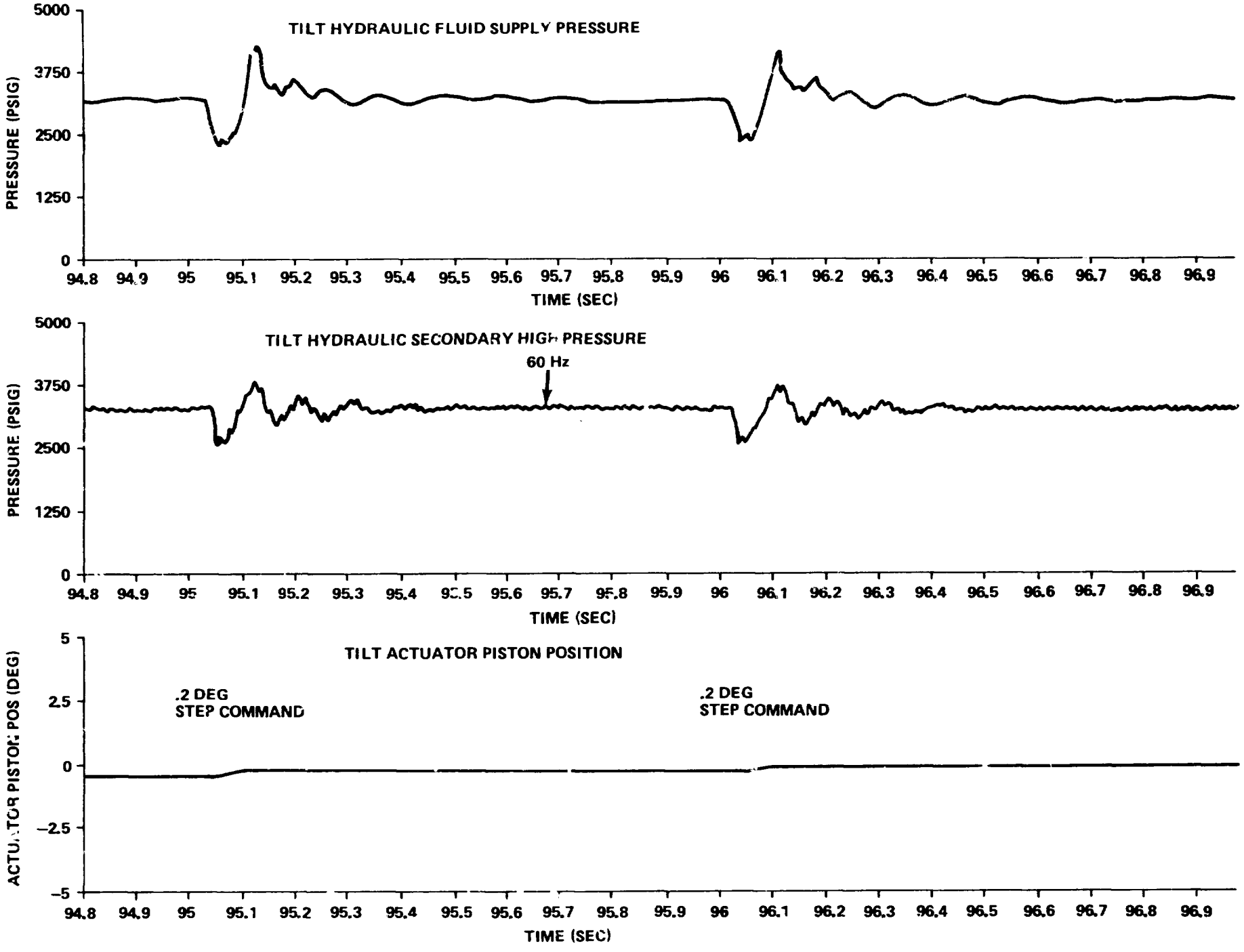




TILT HYDRAULIC HIGH PRESSURE TRANSIENT AT 5 DEG/SEC RAMP
(TEST P037–131)
FIGURE 14



ROCK HYDRAULIC HIGH PRESSURE TRANSIENT AT .2 DEG STEP COMMANDS
(TEST P037–131)
FIGURE 15



TILT HYDRAULIC HIGH PRESSURE TRANSIENT AT .2 DEG STEP COMMANDS
(TEST P037–131)
FIGURE 16

TABLE 9

HYDRAULIC RESERVOIR POSITION AND TEMPERATURE

TEST NO	ROCK SYSTEM HYDRAULIC RESERVOIR POSITION (PCT) START	MIN	MAX	ROCK SYSTEM HYDRAULIC FLUID TEMP (°F) START	END	TILT SYSTEM HYDRAULIC RESERVOIR POSITION (PCT) START	MIN	MAX	TILT SYSTEM HYDRAULIC FLUID TEMP (°F) START	END
P037 – 024	67	64	64	46	46	73	65	65	50	50
– 025	73	71	71	52	57	75	69	69	62	69
– 026	75	66	66	88	109	75	69	72	80	110
– 062	69	67	68	–	–	68	64	65	100	100
– 066	76	74	75	–	–	76	73	73	102	103
– 067	74	72	76	–	–	71	68	72	89	110
– 068	73	72	75	–	–	72	69	69	93	92
– 069	72	71	74	–	–	72	69	72	83	95
– 070	71	70	75	–	–	73	70	74	104	117
– 071	71	69	74	–	–	74	70	75	84	116
– 072	69	68	70	–	–	74	70	76	93	131
– 074	72	58	62	–	–	74	70	76	85	118
– 075	74	71	76	–	–	75	71	75	92	118
– 076	72	69	74	–	–	74	70	75	87	111
– 077	70	69	72	–	–	75	71	75	93	107
– 078	70	69	73	–	–	76	72	78	99	127
– 079	73	72	73	78	78	74	70	70	83	83
– 080	73	73	73	83	83	74	68	69	88	89
– 081	72	70	75	78	98	73	67	72	82	106
– 082	71	70	77	84	113	73	68	70	90	90
– 083	72	71	74	94	105	73	68	73	90	116
– 084	68	66	71	84	106	72	67	72	86	111
– 085	67	66	69	92	105	73	68	73	94	118

TABLE 9

HYDRAULIC RESERVOIR POSITION AND TEMPERATURE (CONT.)

TEST NO	ROCK SYSTEM					TILT SYSTEM				
	HYDRAULIC RESERVOIR POSITION (PCT)			HYDRAULIC FLUID TEMP (°F)		HYDRAULIC RESERVOIR POSITION (PCT)			HYDRAULIC FLUID TEMP (°F)	
	START	MIN	MAX	START	END	START	MIN	MAX	START	END
P037 – 086	66	65	70	95	116	74	70	75	98	124
– 087	66	64	68	83	107	74	69	74	88	112
– 088	65	63	68	91	105	75	71	76	95	124
– 096	74	72	74	88	88	70	66	66	94	94
– 097	72	70	75	83	105	68	65	70	85	116
– 098	71	69	72	81	90	68	64	68	84	105
– 099	71	69	73	77	92	68	65	69	81	115
– 100	70	69	74	82	110	71	67	72	87	120
– 101	70	68	72	85	102	69	66	72	90	124
– 102	69	67	72	73	102	70	66	72	77	110
– 103	69	67	70	84	102	70	66	72	86	122
– 104	68	66	72	93	119	72	68	73	95	131
– 105	68	66	71	86	112	70	67	72	87	119
– 106	67	66	69	85	102	71	66	72	85	120
– 107	70	68	73	72	92	69	65	70	73	103
– 108	66	65	70	87	109	70	67	72	96	121
– 109	72	66	68	67	93	73	69	72	75	95
– 110	68	65	69	50	63	69	64	68	59	69
– 111	68	67	70	60	84	69	66	71	68	92
– 112	68	66	69	63	82	70	66	71	71	88
– 113	66	64	70	63	88	71	68	73	71	94
– 114	65	64	70	55	90	70	68	75	63	146
– 115	65	64	68	68	83	71	68	71	82	87

TABLE 9

HYDRAULIC RESERVOIR POSITION AND TEMPERATURE (CONT.)

	ROCK SYSTEM					TILT SYSTEM				
	HYDRAULIC RESERVOIR POSITION (PCT)			HYDRAULIC FLUID TEMP (°F)		HYDRAULIC RESERVOIR POSITION (PCT)			HYDRAULIC FLUID TEMP (°F)	
TEST NO	START	MIN	MAX	START	END	START	MIN	MAX	START	END
P037– 116	70	67	73	48	72	67	64	69	56	77
– 117	70	68	73	52	76	66	63	68	60	81
– 118	70	68	73	55	79	65	62	67	63	85
– 119	69	67	67	54	54	72	69	77	62	95
– 120	71	69	74	62	88	68	66	71	70	93
– 121	70	69	74	53	74	67	64	69	65	85
– 122	70	68	73	57	82	70	68	73	64	85
– 123	71	70	75	67	91	70	68	73	74	98
– 124	70	68	73	52	77	69	66	71	60	81
– 131	73	72	76	58	73	74	71	75	72	83
– 158	74	72	77	51	74	74	70	75	59	82
– 159	76	75	80	75	99	74	71	76	83	107
– 160	76	74	76	73	77	74	71	72	81	84
– 161	76	75	77	78	81	74	71	72	84	87
– 162	75	73	80	61	96	73	70	70	69	70
– 163	75	73	78	56	80	72	68	73	65	88
– 164	75	74	78	62	77	72	69	73	69	81
– 165	74	73	77	51	66	71	67	71	58	70
– 166	75	74	78	61	85	71	68	73	68	90
– 167	76	75	79	76	92	73	70	74	83	95

Conclusions

The Certification Test Program (V-2) was successfully completed in accordance with SE-019-098-2H; SRB TVC overall system requirements. The following milestones were completed and reported in detail in the body of this report:

a. Total Number of Starts: 66

b. Hot Firing Time: System A (Rock) 9089.8 sec.
System B (Tilt) 9068.4 sec.

c. Spin Test Time: System A 12950.8 sec. (66 starts)
System B 12265.5 sec. (51 starts)

d. Demonstration of Some Level II Requirements:

(1) Gimbal Angle $\pm$ 4.7 deg

(2) Gimbal Rate 5 deg/sec (Nominal operating conditions)
3 deg/sec (Backup mode)

(3) Phase Lag in Frequency Response

(4) Step Commands of .2 deg.

e. Using the hydraulic servicer (577-016), various gimbal programs proposed by KSC were conducted.

A number of other requirements were successfully completed and are enumerated below:

a. Verification of ground servicing procedures using the hydraulic and hydrazine carts, and lube oil servicer.

b. Operation of HPU ground test controller (C77-0204) and TVC system instrumentation, command and cut-off circuitry.

Conclusions (Continued)

c. Demonstration of all the APU speed modes under loaded conditions (100, 110, 112 PCT bine speed).

d. Confirm the adequacy of hydraulic fluid and hydrazine contamiantion levels.

e. The verification program helped develop a data base that will prove invaluable in support of Thiokol's TVC tests and KSC's TVC systems operation.

f. Checkout of MSFC-TVC hot firing van using prescribed programs from the certification matrix.

g. Provide operational validity of TVC system redlines and nominal operation bands.

APPENDIX

A

ACTUATOR

GIMBAL PROGRAMS

FIGURE A–1

C GIMBAL PROGRAM

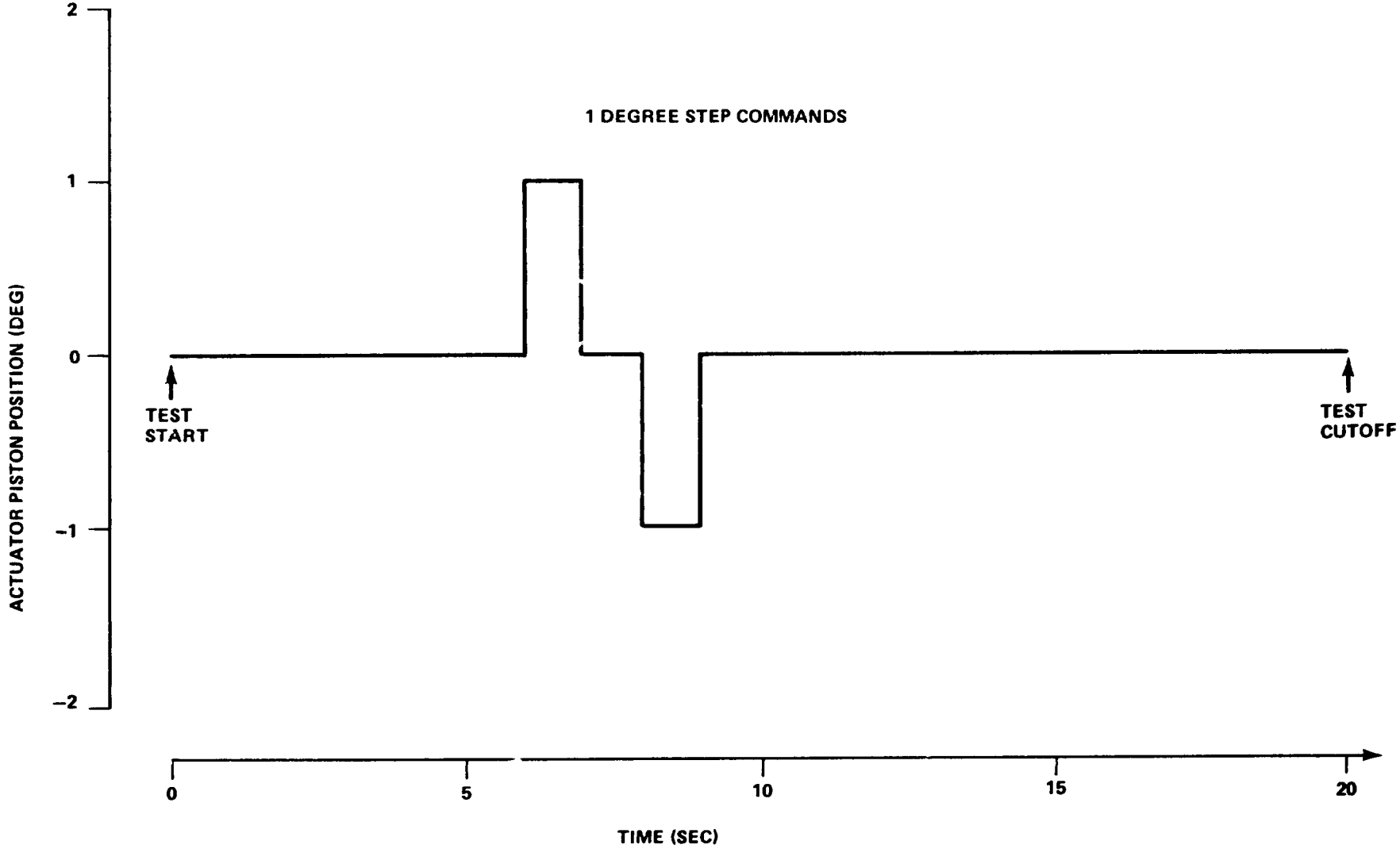


FIGURE A–2

CI GIMBAL PROGRAM (KSC CHECKOUT TEST) *

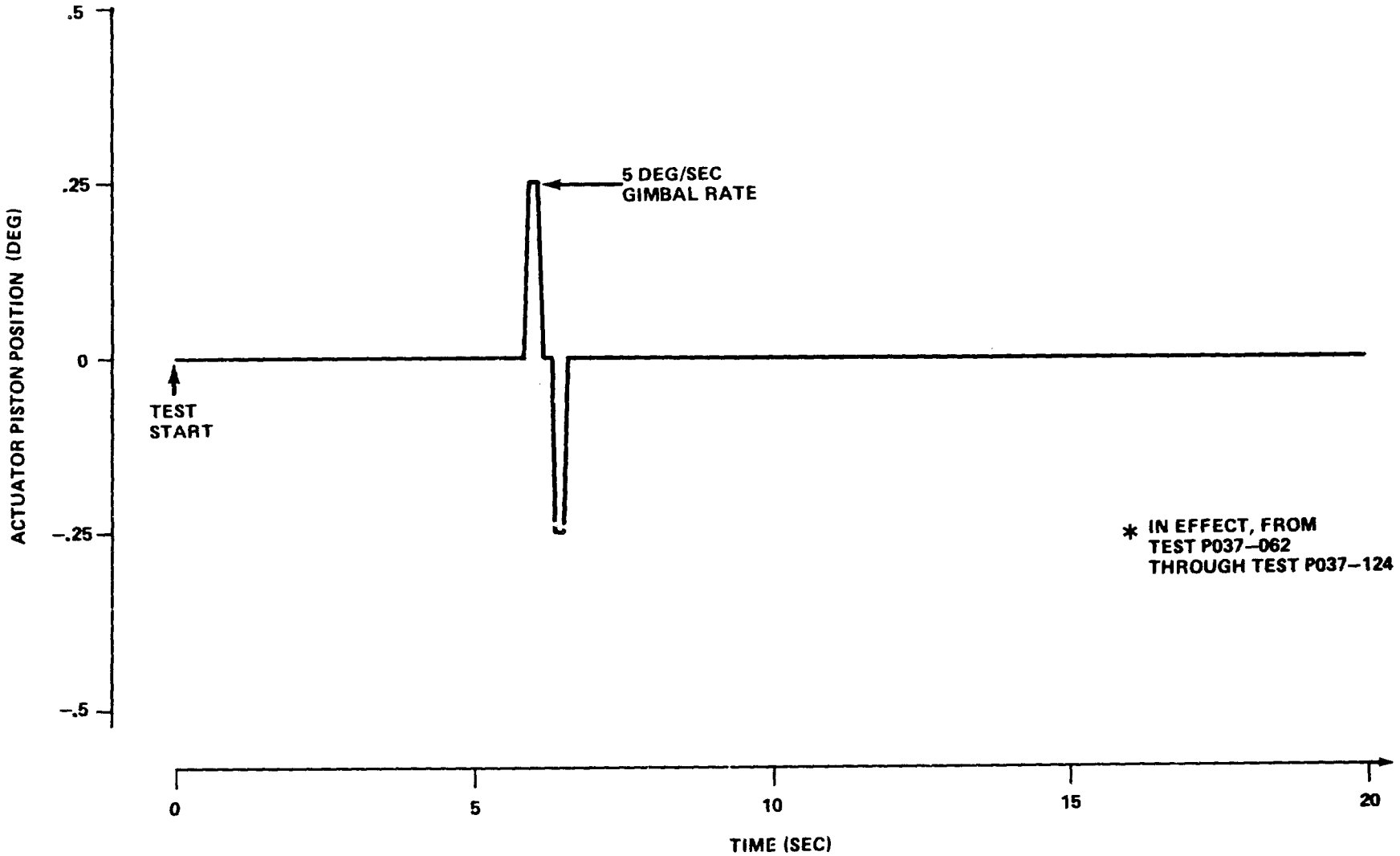


FIGURE A–3

C2 GIMBAL PROGRAM*
(KSC CHECKOUT PROFILE)

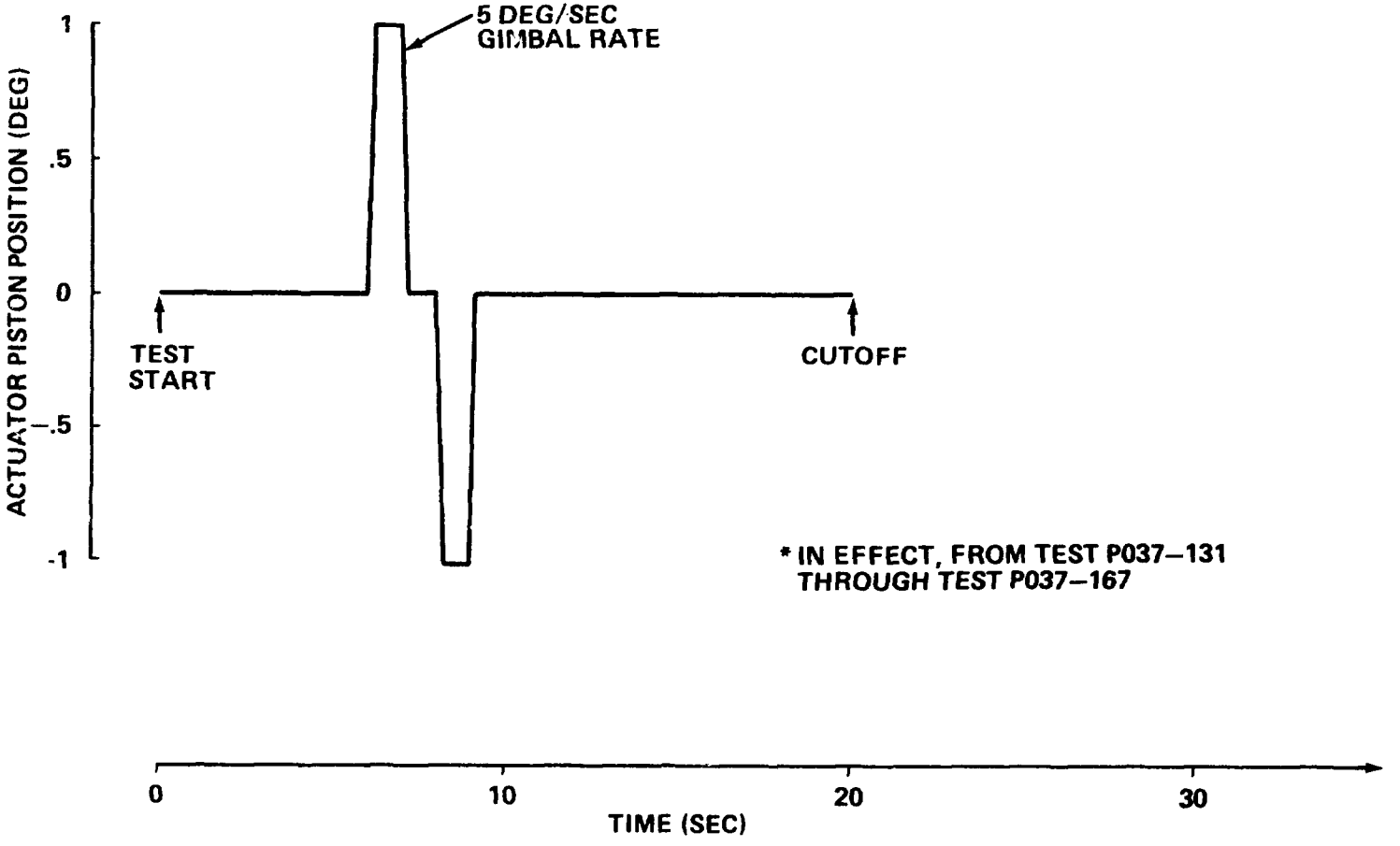


FIGURE A–4

D GIMBAL PROGRAM

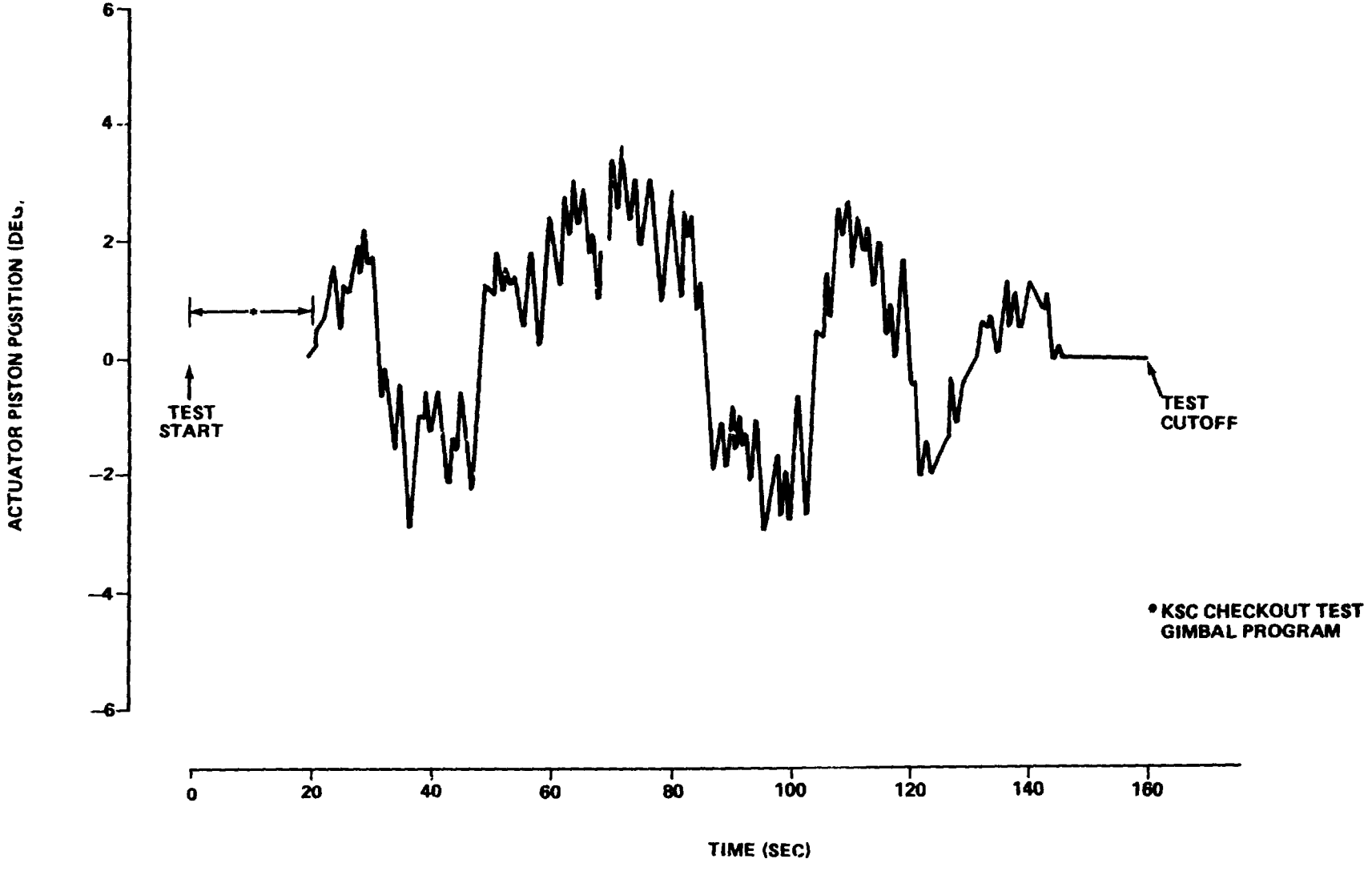
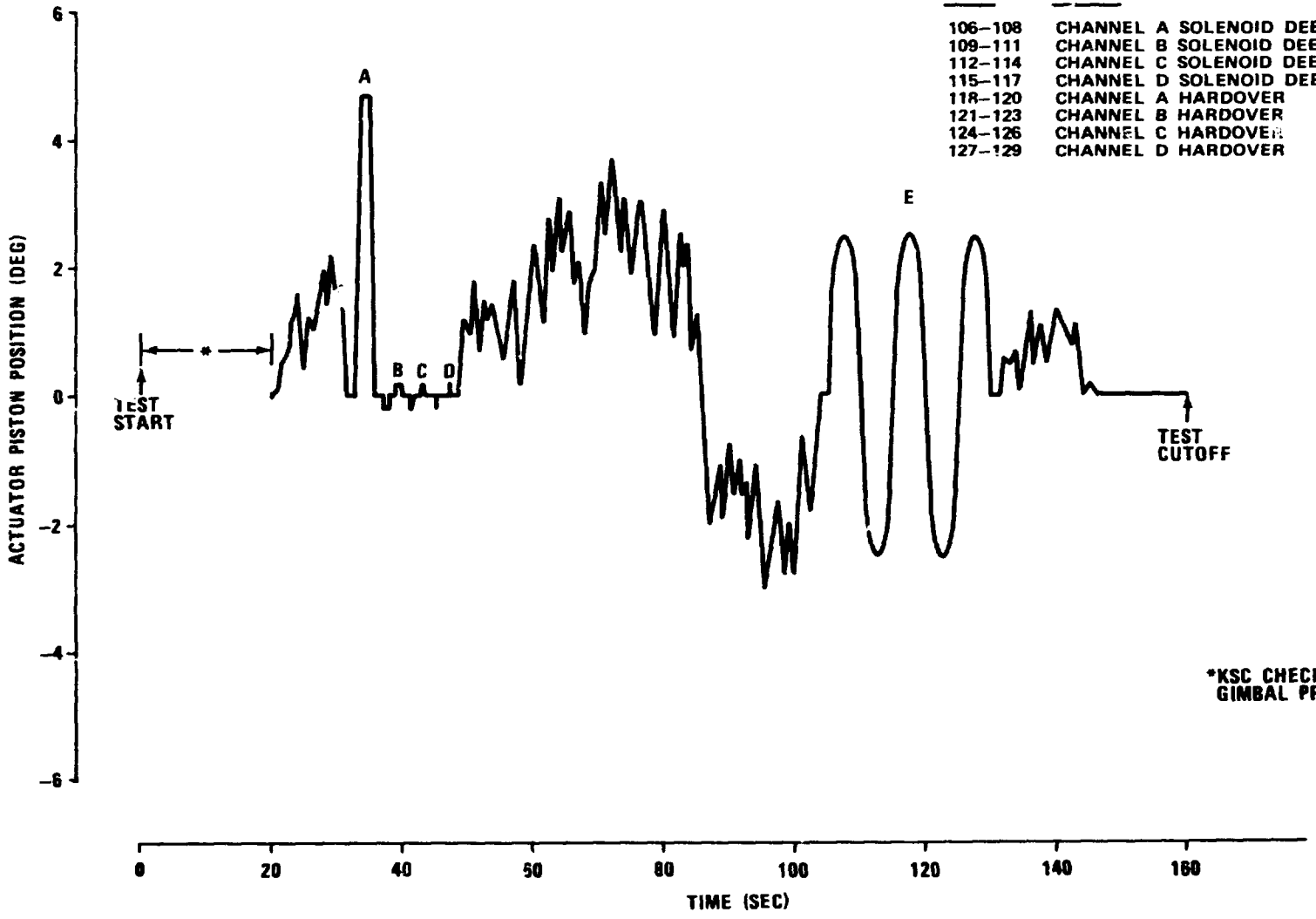


FIGURE A–5

E GIMBAL PROGRAM

A 5 DEG/SEC RAMPS (HALF A CYCLE)
B .2 DEG STEP COMMANDS (ONE CYCLE)
C SINE WAVE 1 HZ (TWO HALF CYCLES)
D SINE WAVE 3 HZ (TWO HALF CYCLES)
E ACTUATOR SERVOVALVE REDUNDANCY TEST (105–130 SEC)

TIME	EVENT
106–108	CHANNEL A SOLENOID DEENERGIZED
109–111	CHANNEL B SOLENOID DEENERGIZED
112–114	CHANNEL C SOLENOID DEENERGIZED
115–117	CHANNEL D SOLENOID DEENERGIZED
118–120	CHANNEL A HARDOVER
121–123	CHANNEL B HARDOVER
124–126	CHANNEL C HARDOVER
127–129	CHANNEL D HARDOVER



*KSC CHECKOUT TEST GIMBAL PROGRAM

FIGURE A–6

FI GIMBAL PROGRAM

A. KSC CHECKOUT TEST GIMBAL PROGRAM

B.

	FREQUENCY RESPONSE (SINE WAVE) FREQUENCY (HZ)	CYCLES	TIME (SEC)
A	.3	2.5	103–111
B	.5	2	112–116
C	1.0	4	117–121
D	2.0	4	122–124
E	4.0	8	125–127
F	6.0	12	128–130
G	8.0	16	131–133
H	10.0	20	134–136
I	12.0	24	137–139
J	16.0	32	140–142

AMPLITUDE ± .15°

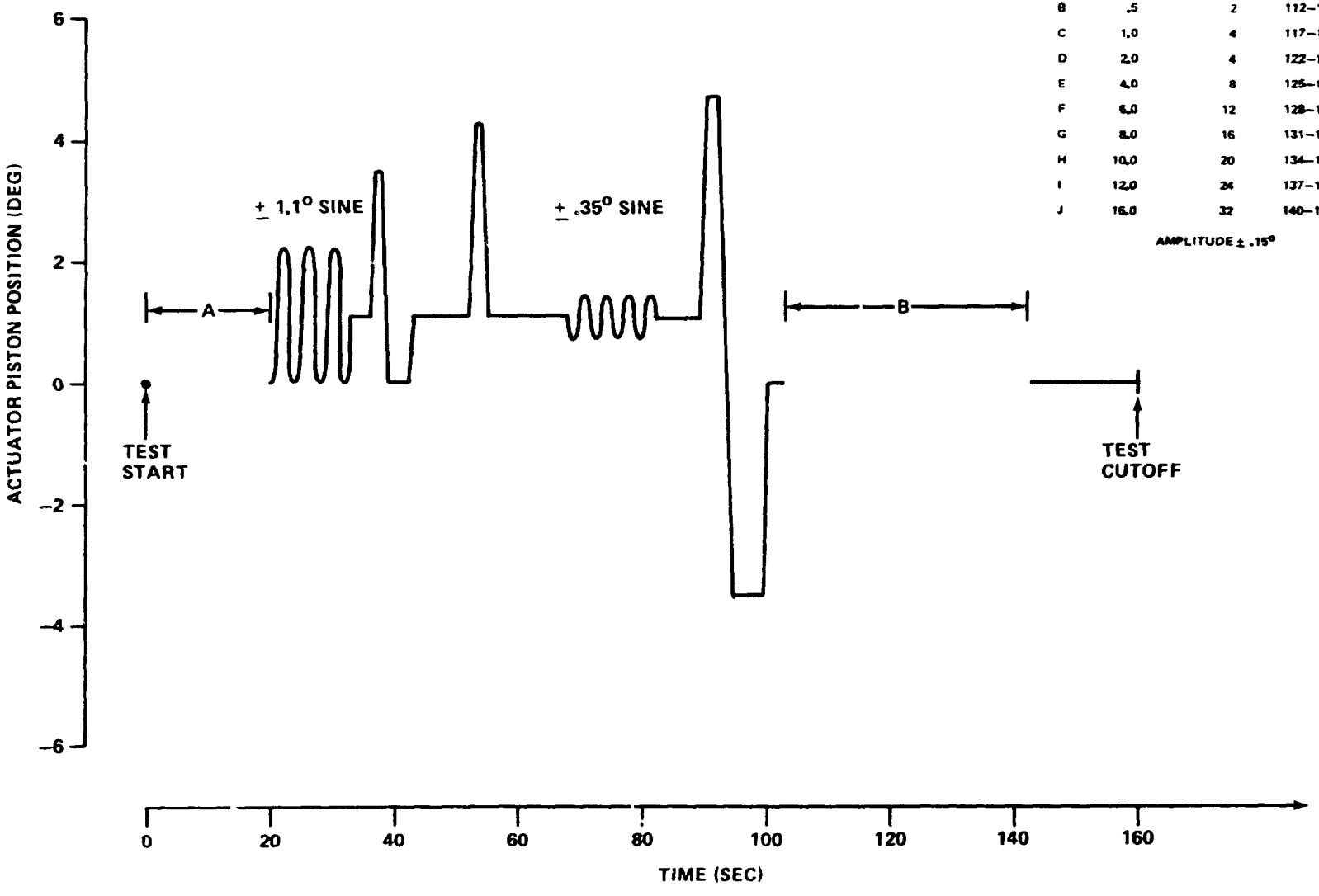
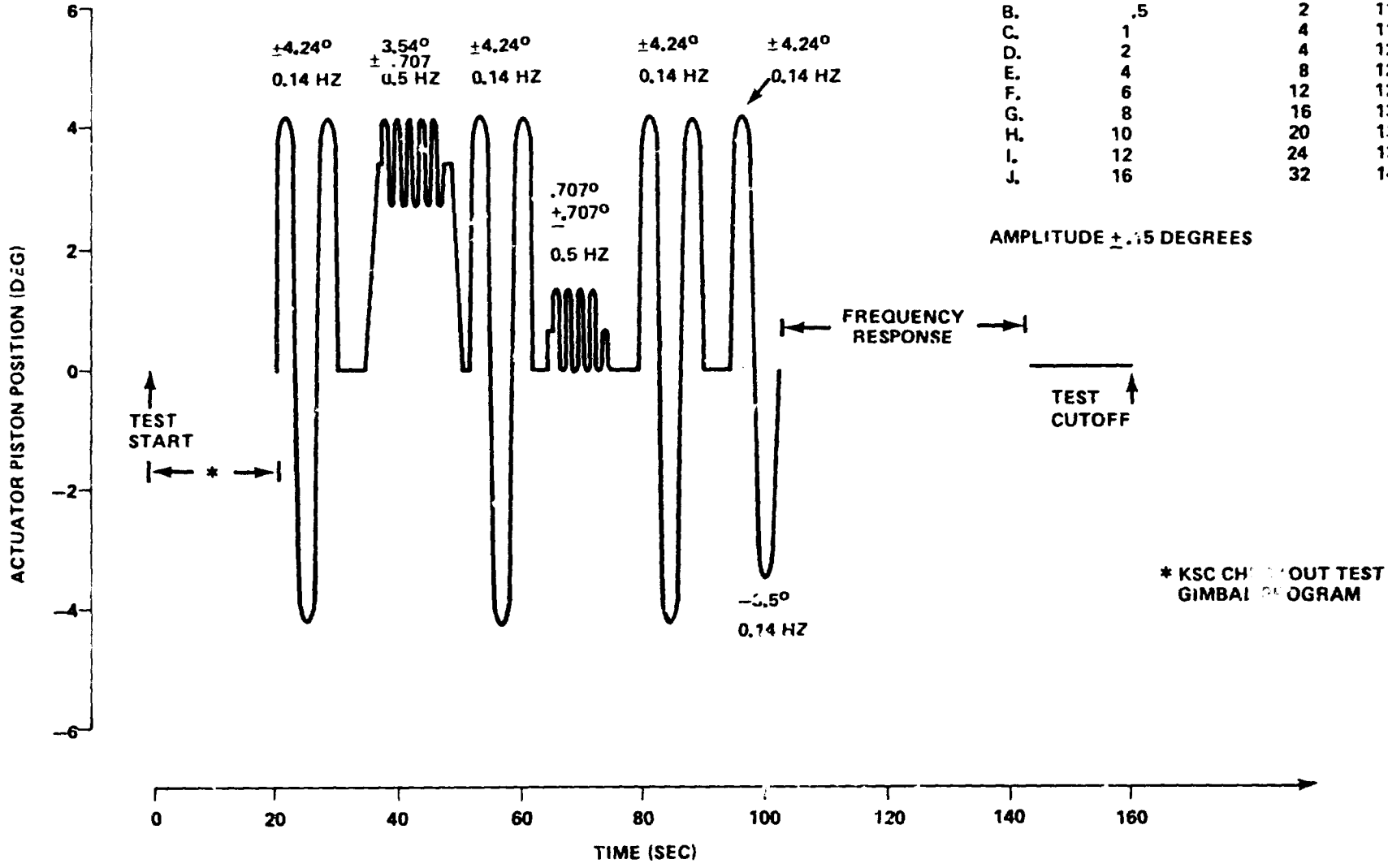


FIGURE A–7

F2 GIMBAL PROGRAM



FREQUENCY RESPONSE (SINE WAVE)

	FREQUENCY (Hz)	CYCLES	TIME (SEC)
A.	.3	2.5	103–111
B.	.5	2	113–117
C.	1	4	118–122
D.	2	4	123–125
E.	4	8	126–128
F.	6	12	129–131
G.	8	16	132–134
H.	10	20	135–137
I.	12	24	138–140
J.	16	32	141–143

AMPLITUDE ±.15 DEGREES

* KSC CHECKOUT TEST GIMBAL PROGRAM

FIGURE A–8

F3 GIMBAL PROGRAM

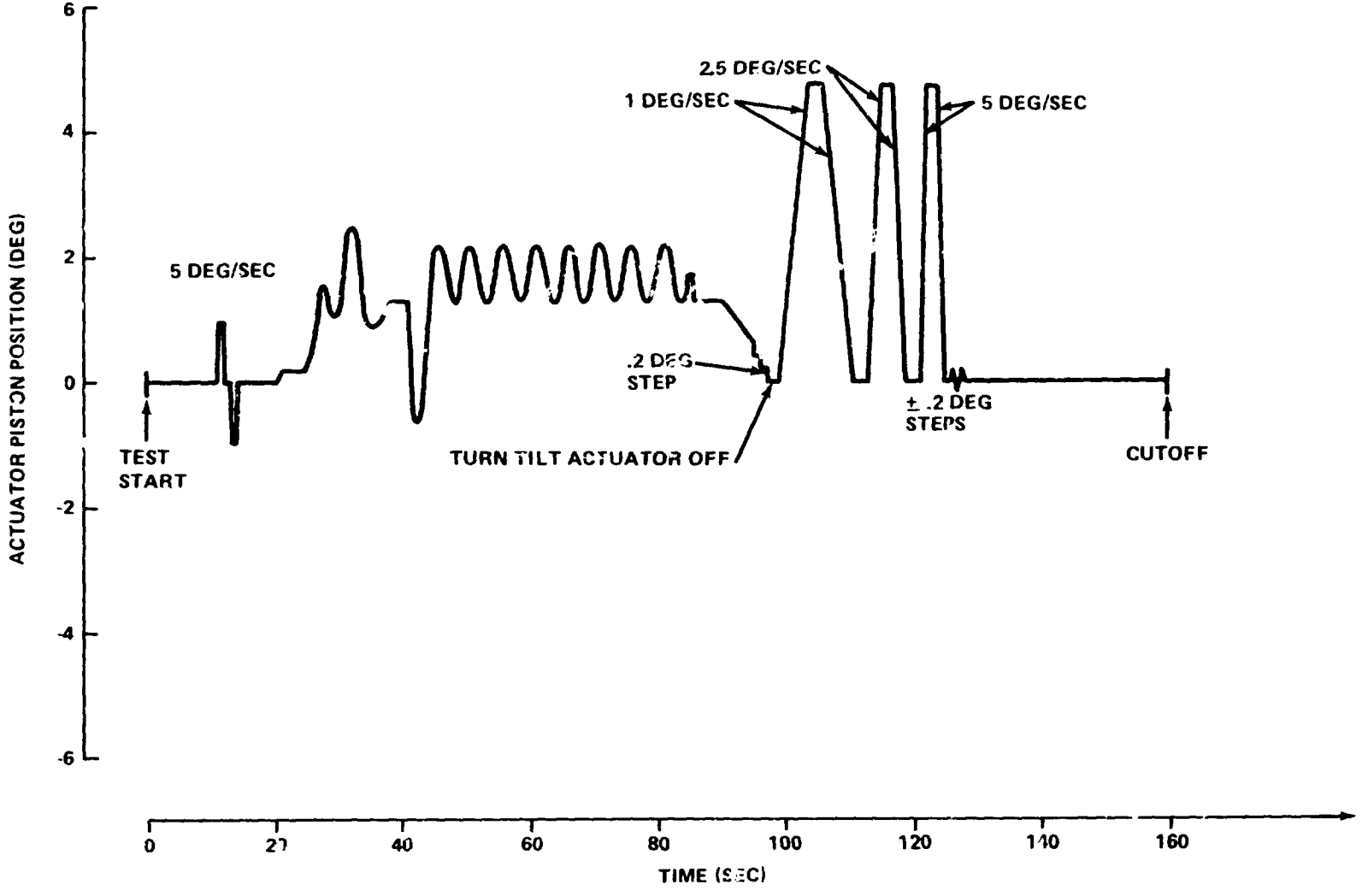


FIGURE A–9

G GIMBAL PROGRAM

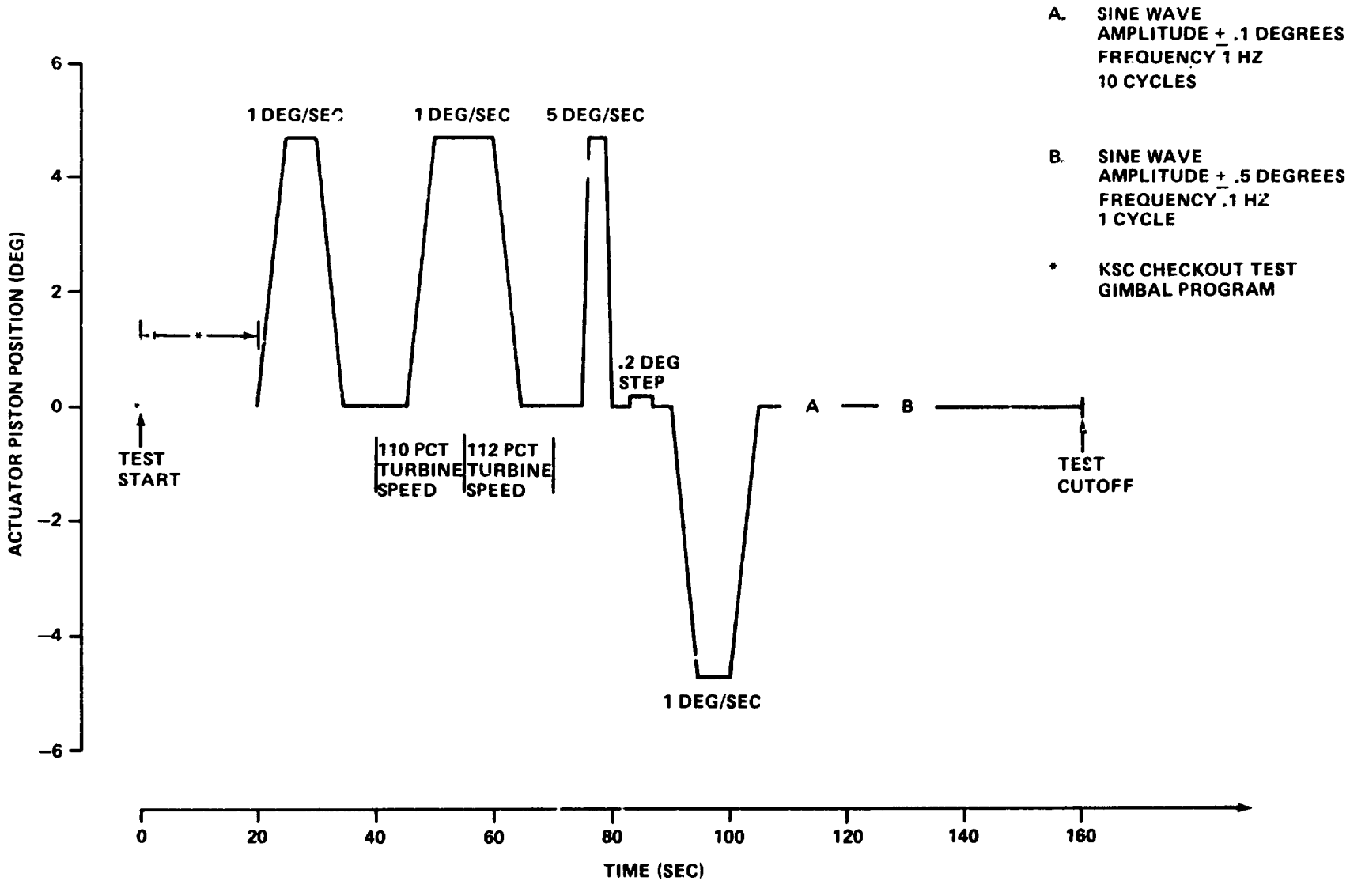


FIGURE A–10

H GIMBAL PROGRAM

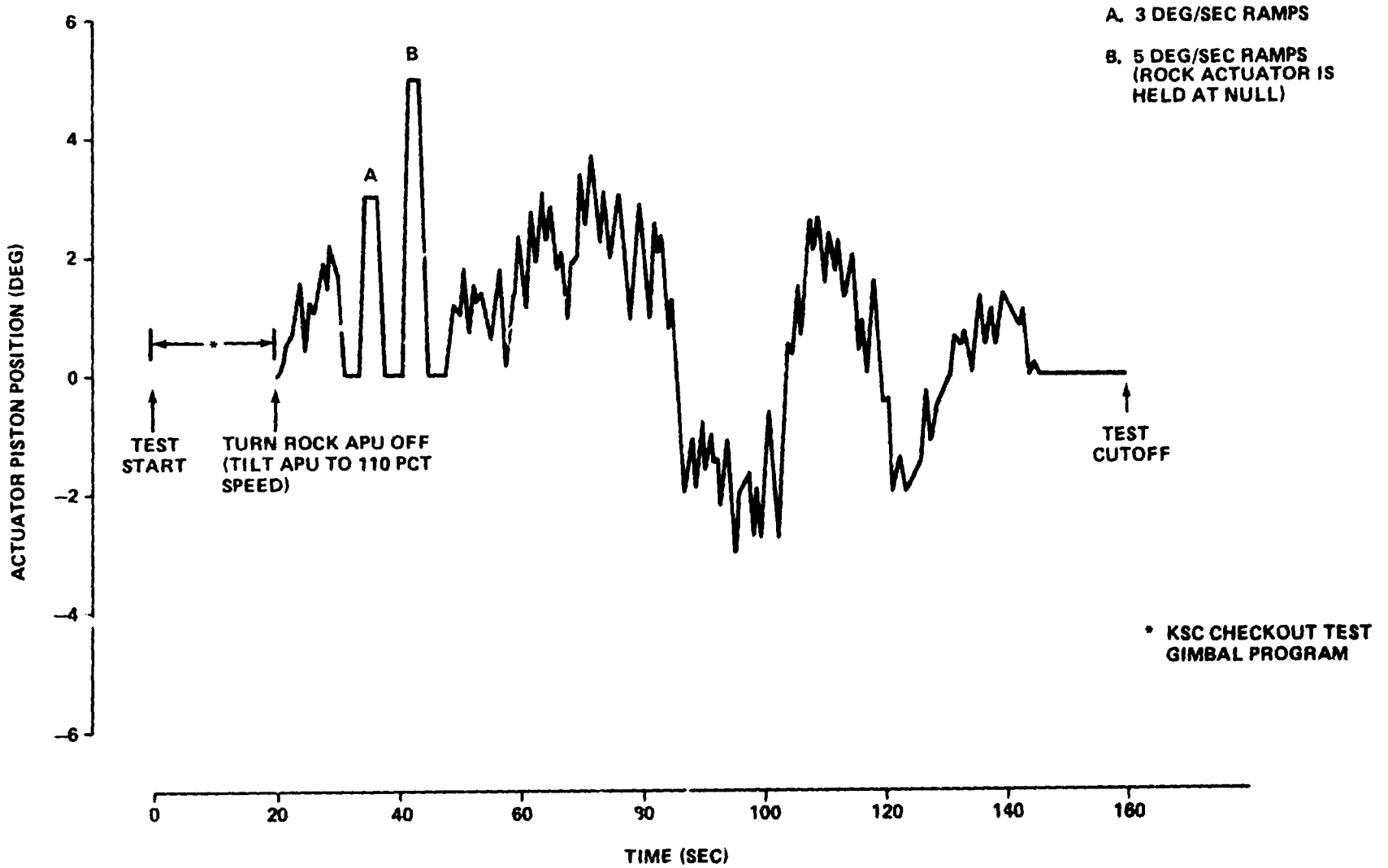


FIGURE A–11

Test I

FOR TEST I

USE D GIMBAL PROGRAM

AND USE

A TURBINE SPEED OF

(1) 100 PCT FROM START TO 86 SEC

(2) 112 PCT FROM 86 SEC TO CUTOFF

FIGURE A–12
J GIMBAL PROGRAM

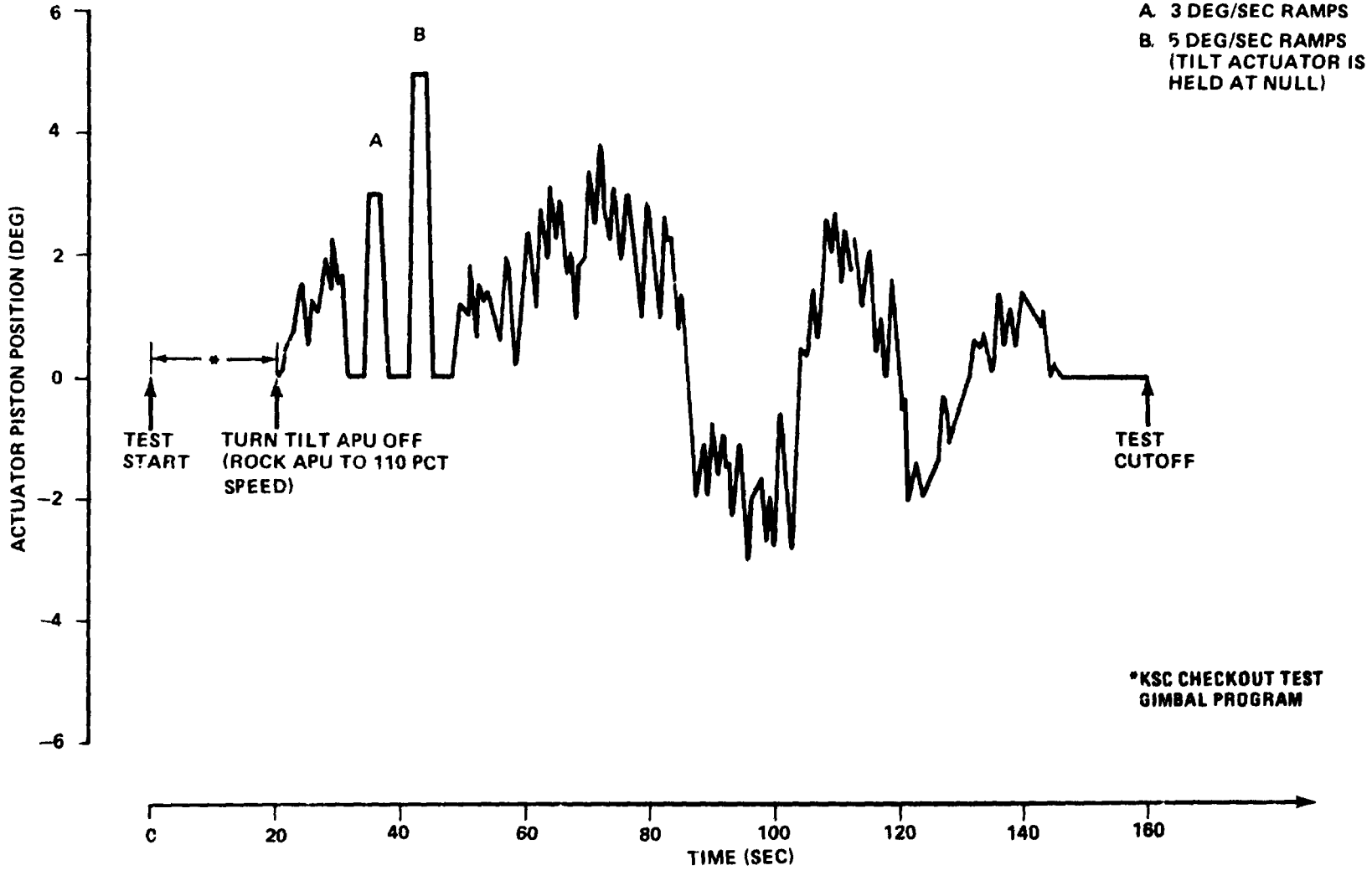
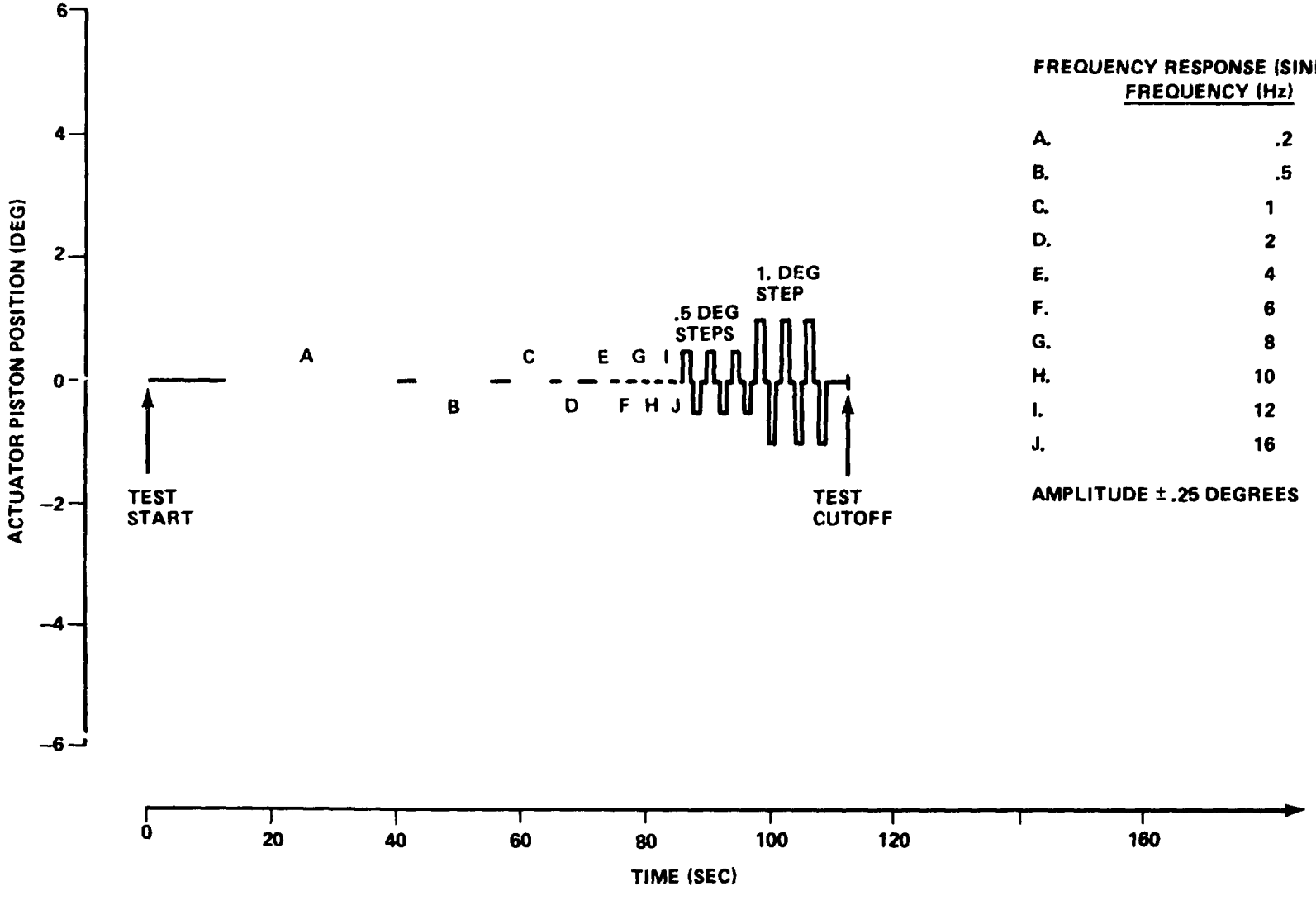


FIGURE A–13
L GIMBAL PROGRAM

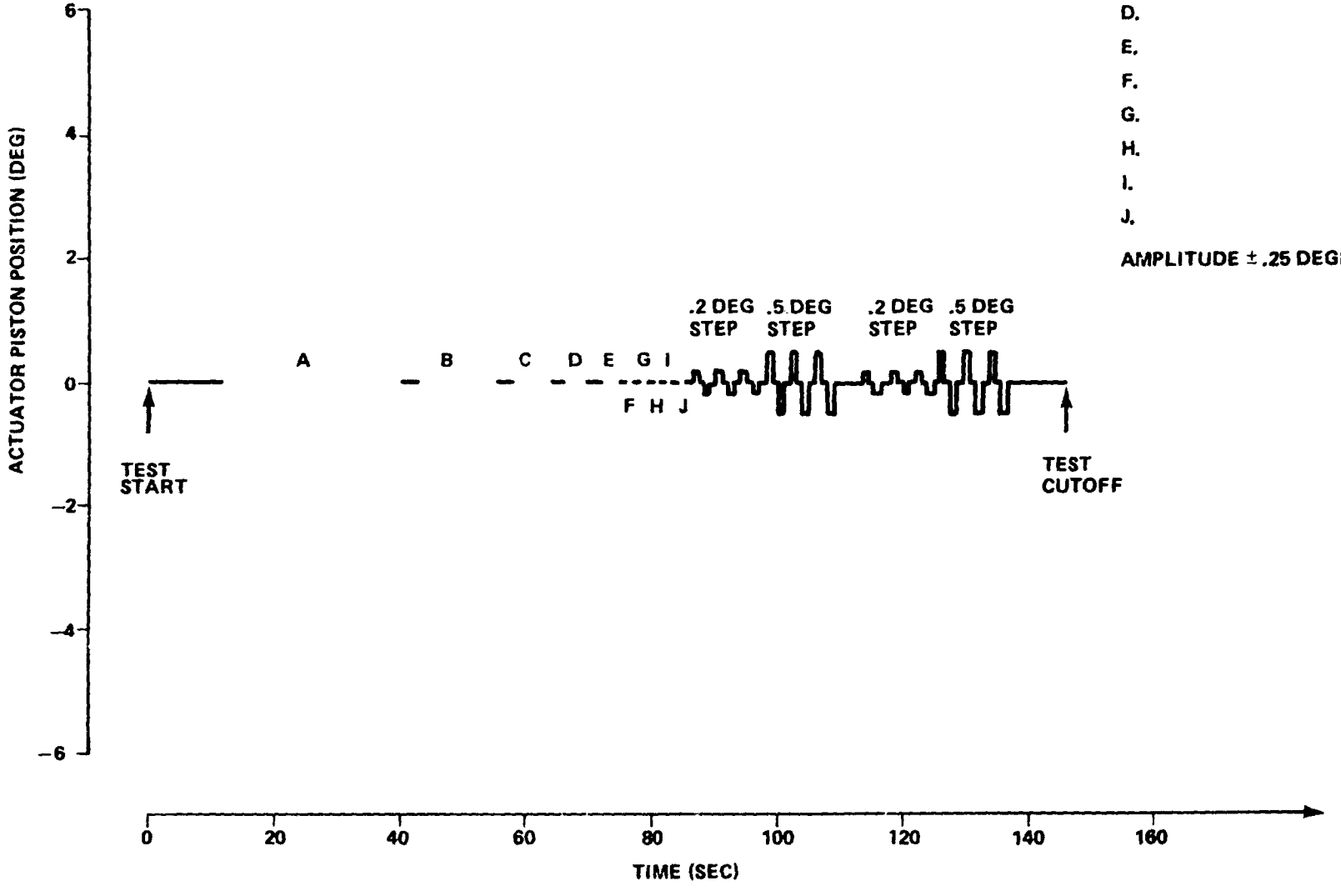


FREQUENCY RESPONSE (SINE WAVE)

	FREQUENCY (Hz)
A.	.2
B.	.5
C.	1
D.	2
E.	4
F.	6
G.	8
H.	10
I.	12
J.	16

AMPLITUDE ± .25 DEGREES

FIGURE A–14
M GIMBAL PROGRAM



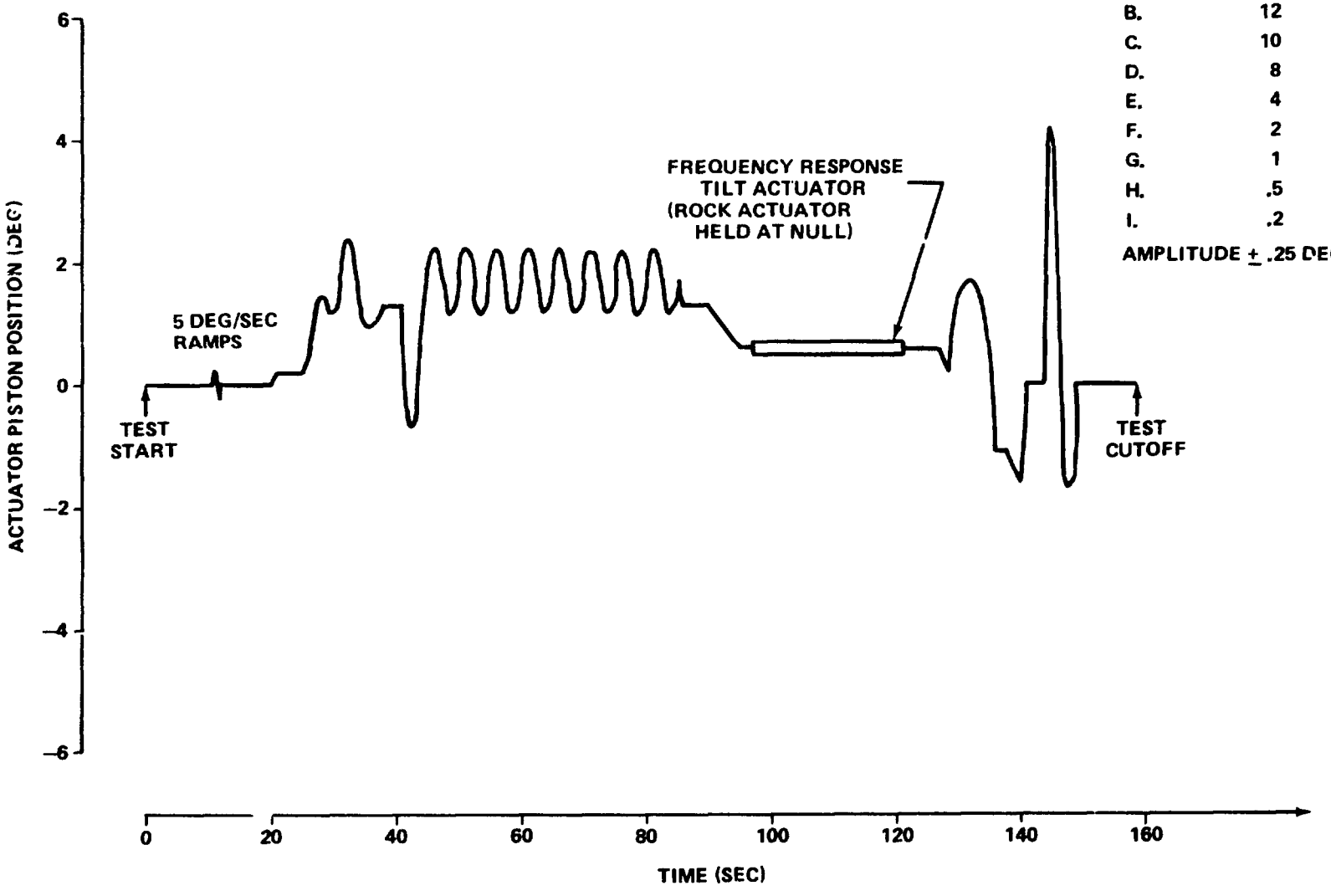
FREQUENCY RESPONSE (SINE WAVE)

	FREQUENCY Hz
A.	.2
B.	.5
C.	1
D.	2
E.	4
F.	6
G.	8
H.	10
I.	12
J.	16

AMPLITUDE ± .25 DEGREES

FIGURE A–15

N* GIMBAL PROGRAM



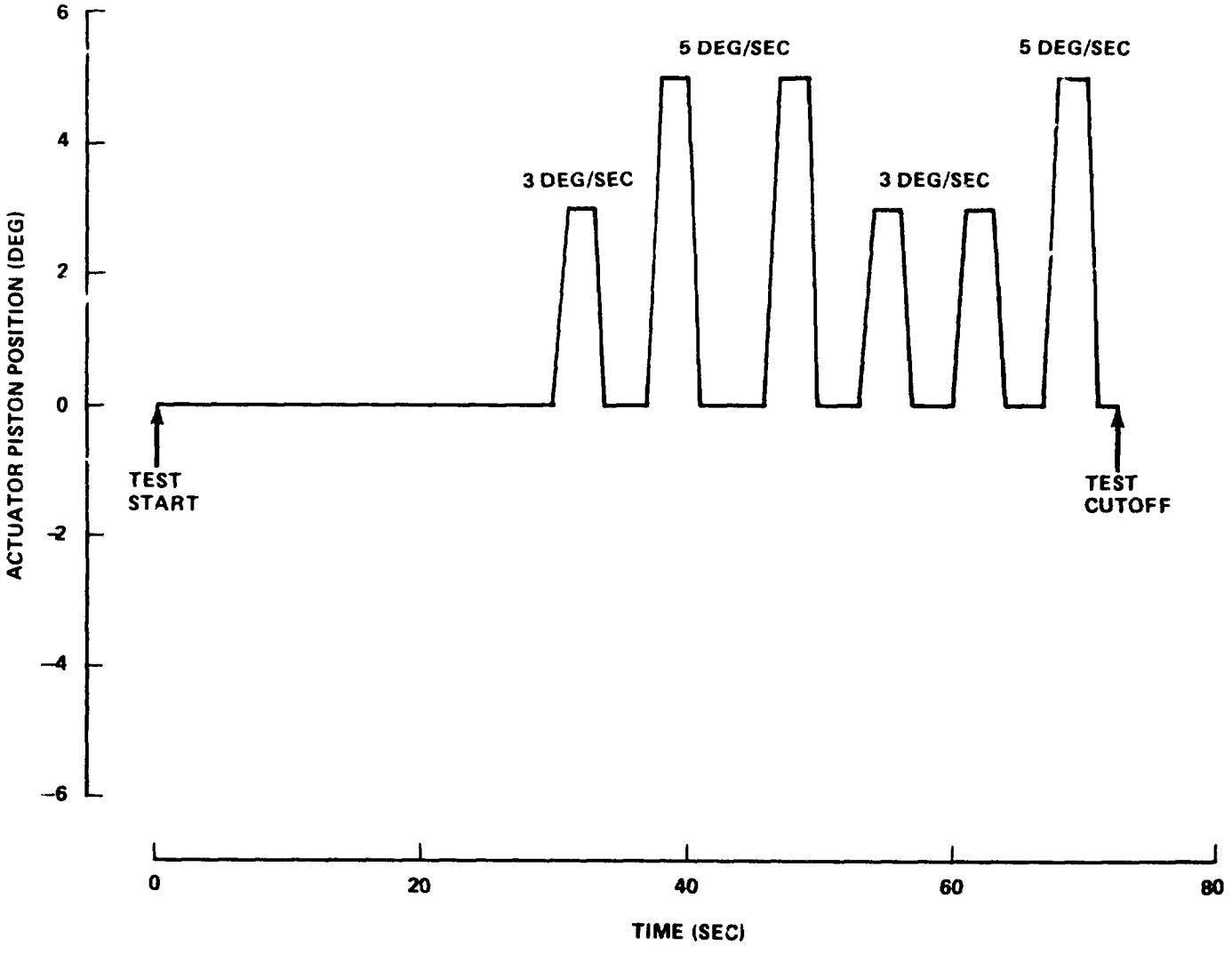
FREQUENCY RESPONSE (SINE WAVE)

	FREQUENCY (Hz)	CYCLES
A.	16	24
B.	12	18
C.	10	15
D.	8	12
E.	4	8
F.	2	5
G.	1	4
H.	.5	2
I.	.2	1

AMPLITUDE ± .25 DEGREES

FIGURE A–16

" SPECIAL" GIMBAL PROGRAM



APPENDIX

B

FUEL SUPPLY MODULE

TEMPERATURE AND PRESSURE

FUEL SUPPLY MODULE TEMPERATURE AND PRESSURE

TEST NUMBER	ROCK SYSTEM FSM TEMPERATURE (°F)	ROCK SYSTEM FSM PRESSURE (PSIG) START	ROCK SYSTEM FSM PRESSURE (PSIG) END	TILT SYSTEM FSM TEMPERATURE (°F)	TILT SYSTEM FSM PRESSURE (PSIG) START	TILT SYSTEM FSM PRESSURE (PSIG) END
P037 – 024	62	374	356	54	375	359
– 025	63	373	323	68	375	319
– 026	79–80	376	289	77–78	375	288
– 062	89–90	376	360	86	375	360
– 066	88	374	366	–	374	348
– 067	86	378	307	84	373	303
– 068	85–86	375	326	84	368	360
– 069	79–80	376	310	77–78	373	310
– 070	86	376	299	84	373	297
– 071	83	375	291	80	376	295
– 072	91	378	363	86–88	376	278
– 074	82–83	379	292	80	374	291
– 075	87–88	379	303	85–86	372	299
– 076	83	371	284	81–82	370	297
– 077	87–88	378	310	84–85	378	309
– 078	90	375	289	87–89	371	295
– 079	79–80	377	345	76	376	368
– 080	84	373	359	1	377	369
– 081	78–79	374	290	76	371	294
– 082	82	377	269	80	373	354
– 083	83	374	302	79–80	378	306
– 084	84–85	374	294	80–82	375	297
– 085	88	373	307	84–86	375	304
– 096	89–90	374	299	86–87	373	296

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TABLE B–1

FUEL SUPPLY MODULE TEMPERATURE AND PRESSURE

TEST NUMBER	ROCK SYSTEM			TILT SYSTEM		
	FSM TEMPERATURE (°F)	FSM PRESSURE (PSIG)		FSM TEMPERATURE (°F)	FSM PRESSURE (PSIG)	
		START	END		START	END
F037 – 087	86	370	292	83–84	374	297
– 088	87–88	369	313	85–87	373	286
– 096	88	356	342	87	357	339
– 097	83–84	351	276	82–83	372	285
– 098	81	372	315	81	364	312
– 099	76	369	303	76	363	291
– 100	78	372	296	77	376	297
– 101	85	375	304	84–86	375	297
– 102	75	375	300	73–74	375	297
– 103	84	396	320	82–84	393	306
– 104	86	387	306	83–84	390	303
– 105	85–86	393	312	83–84	387	303
– 106	81	387	315	80	387	303
– 107	70	381	300	71	379	298
– 108	87	381	299	84–86	379	298
– 109	69–70	371	312	68	368	311
– 110	57–58	380	311	56–57	377	311
– 111	58	376	308	55–57	381	308
– 112	61	378	312	57–58	375	310
– 113	62–63	384	303	60–61	383	302
– 114	55	373	308	53–54	375	304
– 115	57–59	375	306	56–57	373	311
– 116	50–52	384	302	46–48	380	300
– 117	52	376	299	49–50	374	298

TABLE B–1

FUEL SUPPLY MODULE TEMPERATURE AND PRESSURE

TEST NUMBER	ROCK SYSTEM			TILT SYSTEM		
	FSM TEMPERATURE (°F)	FSM PRESSURE (PSIG)		FSM TEMPERATURE (°F)	FSM PRESSURE (PSIG)	
		START	END		START	END
P037 – 118	53–55	378	300	51–53	378	301
– 119	54–55	373	360	52–54	371	273
– 120	62–63	376	296	59–61	372	294
– 121	57–58	380	301	56–57	377	297
– 122	57–59	375	298	54–56	375	299
– 123	67–69	376	293	67	376	293
– 124	54	374	292	52–53	377	297
– 131	54	365	297	50	359	292
– 158	49–50	376	292	47	372	294
– 159	74	372	294	71–73	371	296
– 160	73	376	337	72	378	[illegible]6
– 161	73	376	348	68	371	345
– 162	64	378	275	63	378	360
– 163	57–58	377	298	56	369	291
– 164	63–64	377	307	62	376	308
– 165	52–54	378	306	50	379	307
– 166	59	380	305	55	370	298
– 167	75	372	306	72–73	367	302

APPENDIX

C

OPERATION PARAMETERS

FOR SELECTED TESTS

TEST P037-077

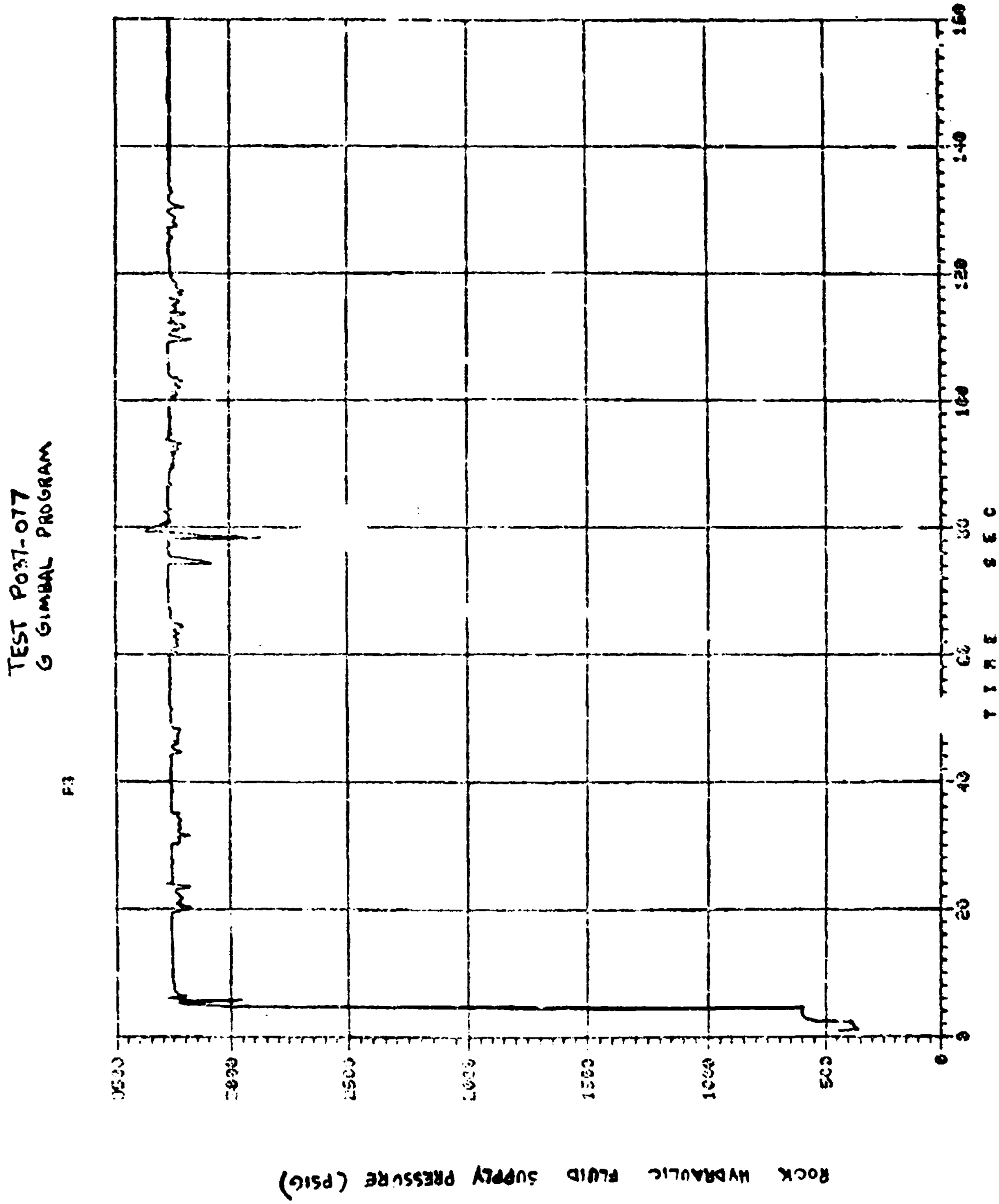


FIGURE C–1

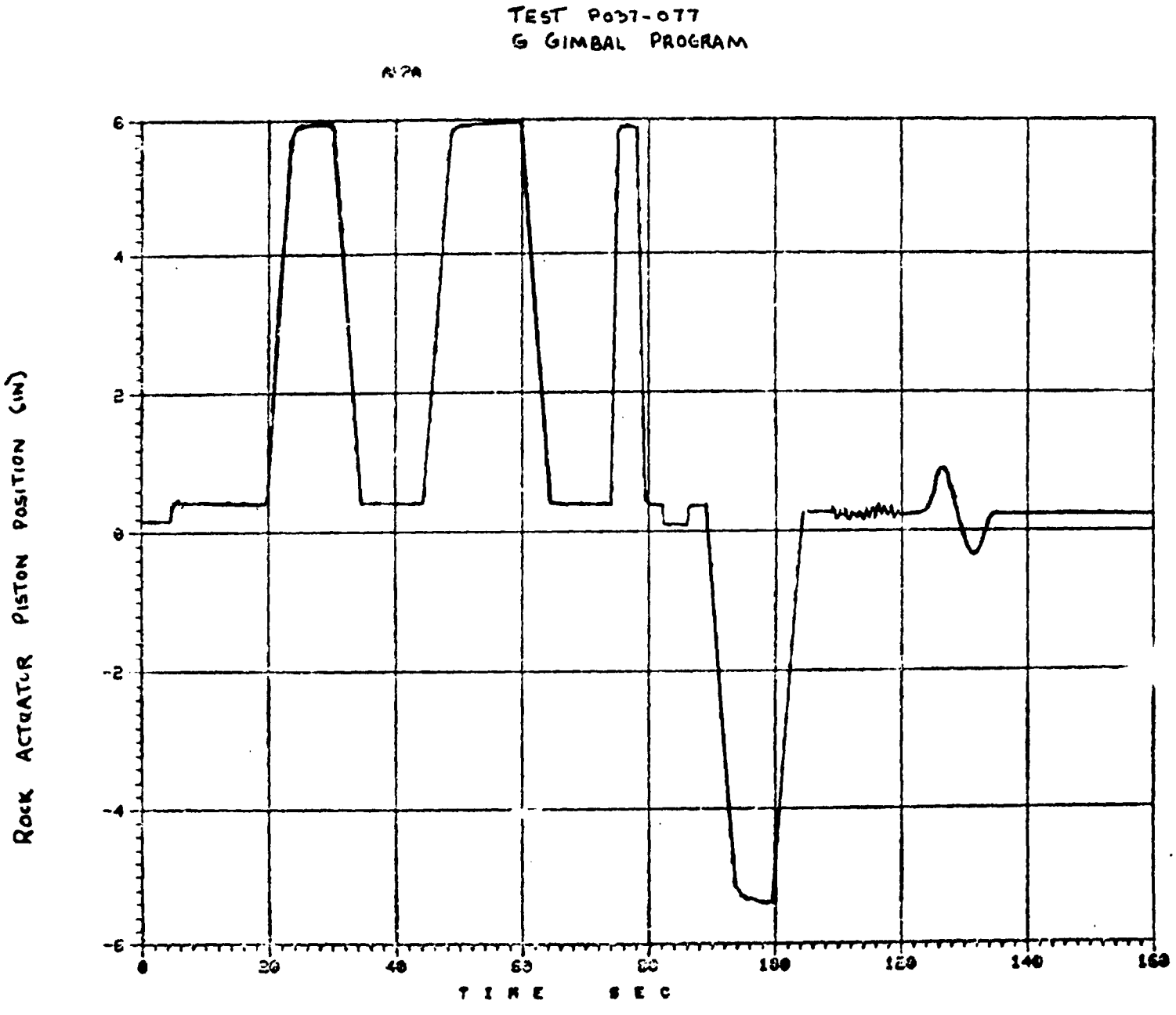
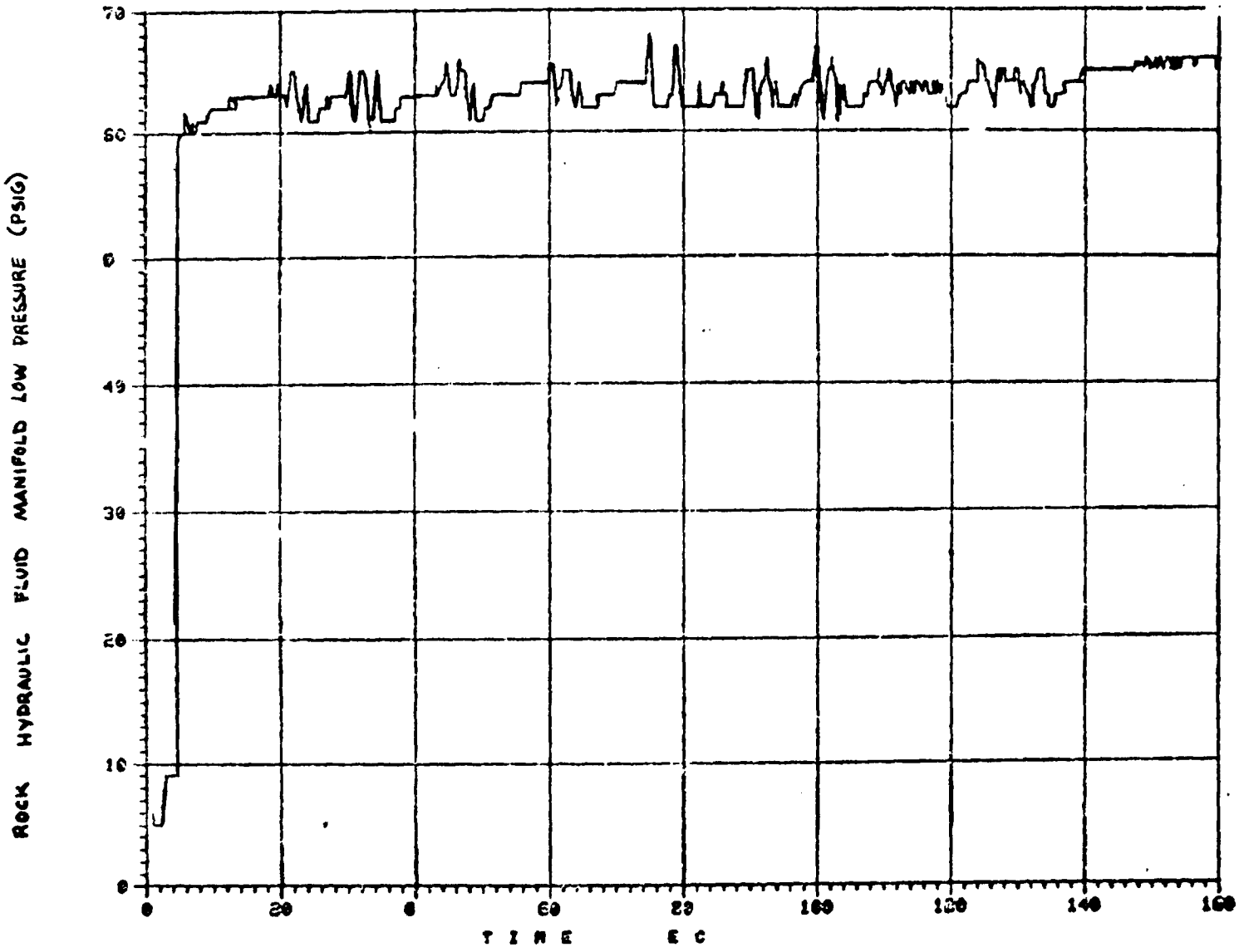

TEST P037-077
G GIMBAL PROGRAM
ROCK ACTUATOR PISTON POSITION (IN)
6
4
2
0
-2
-4
-6
0
20
40
60
80
100
120
140
160
TIME SEC

FIGURE C–2

TEST P037-077
G GIMBAL PROGRAM

LP1



TEST P037-077
G GIMBAL PROGRAM

P5

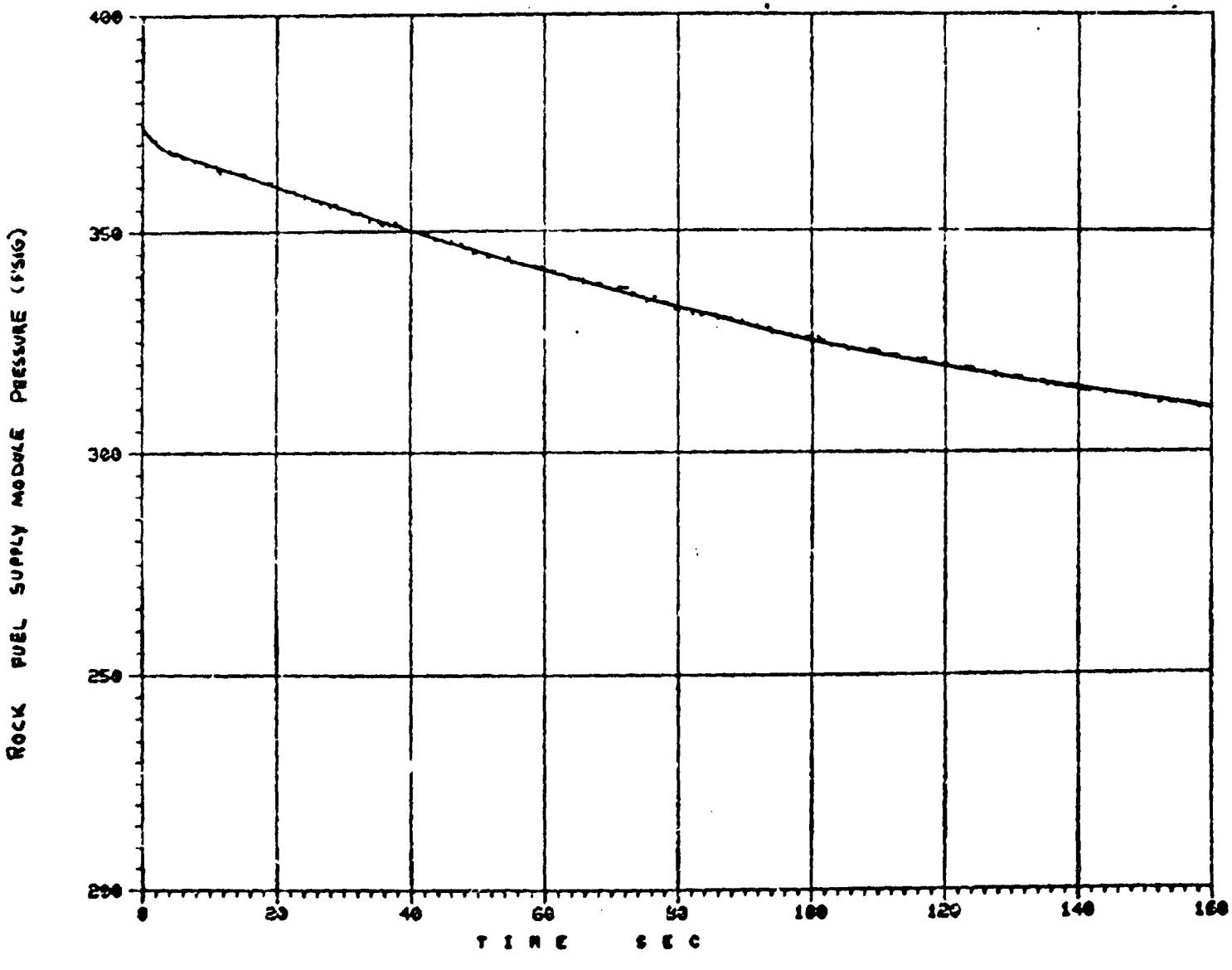


FIGURE C-4

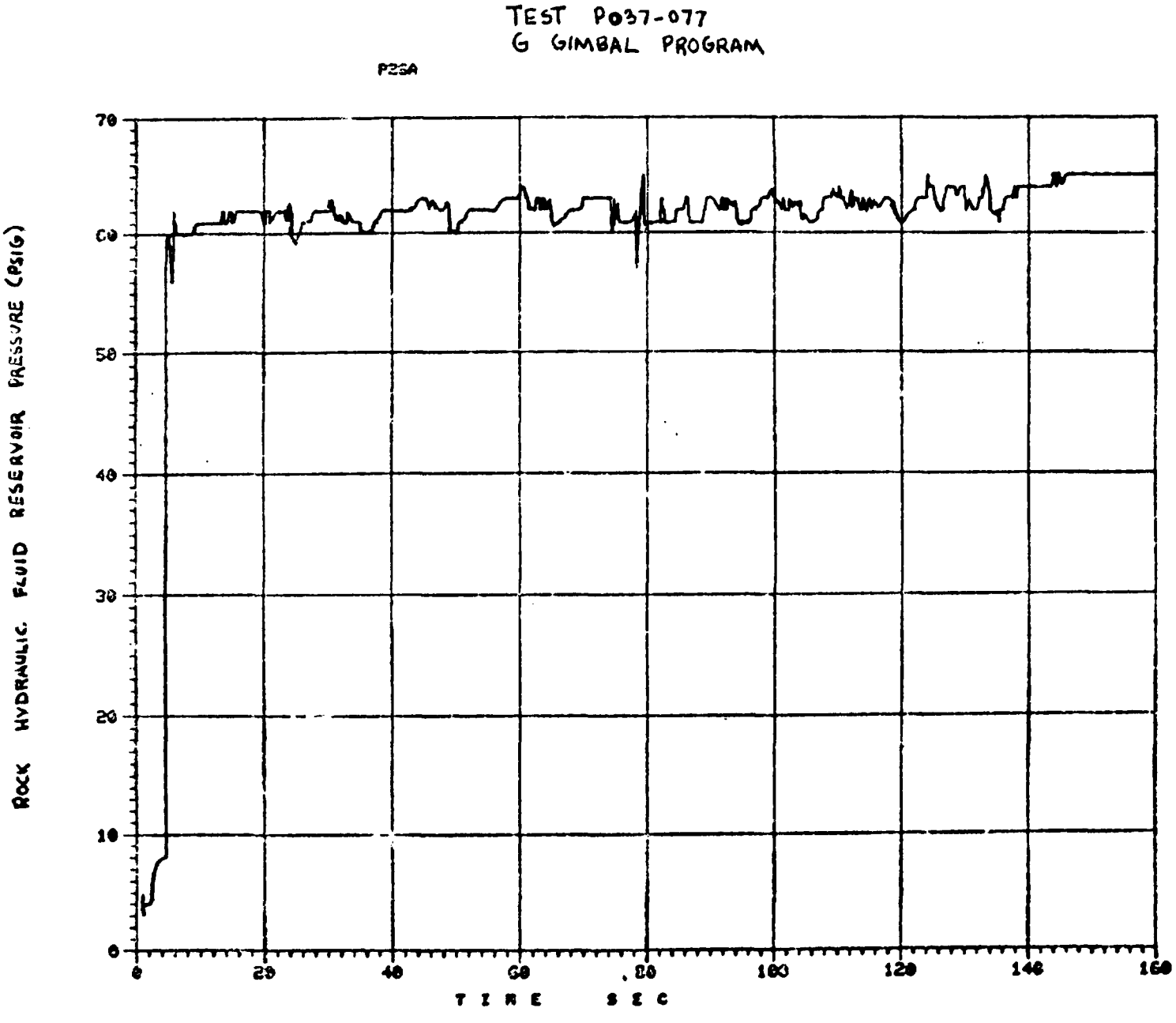

TEST P037-077
G GIMBAL PROGRAM
P23A
ROCK HYDRAULIC FLUID RESERVOIR PRESSURE (PSIG)
70
60
50
40
30
20
10
0
0
20
40
60
80
100
120
140
160
TIME SEC

FIGURE C–5

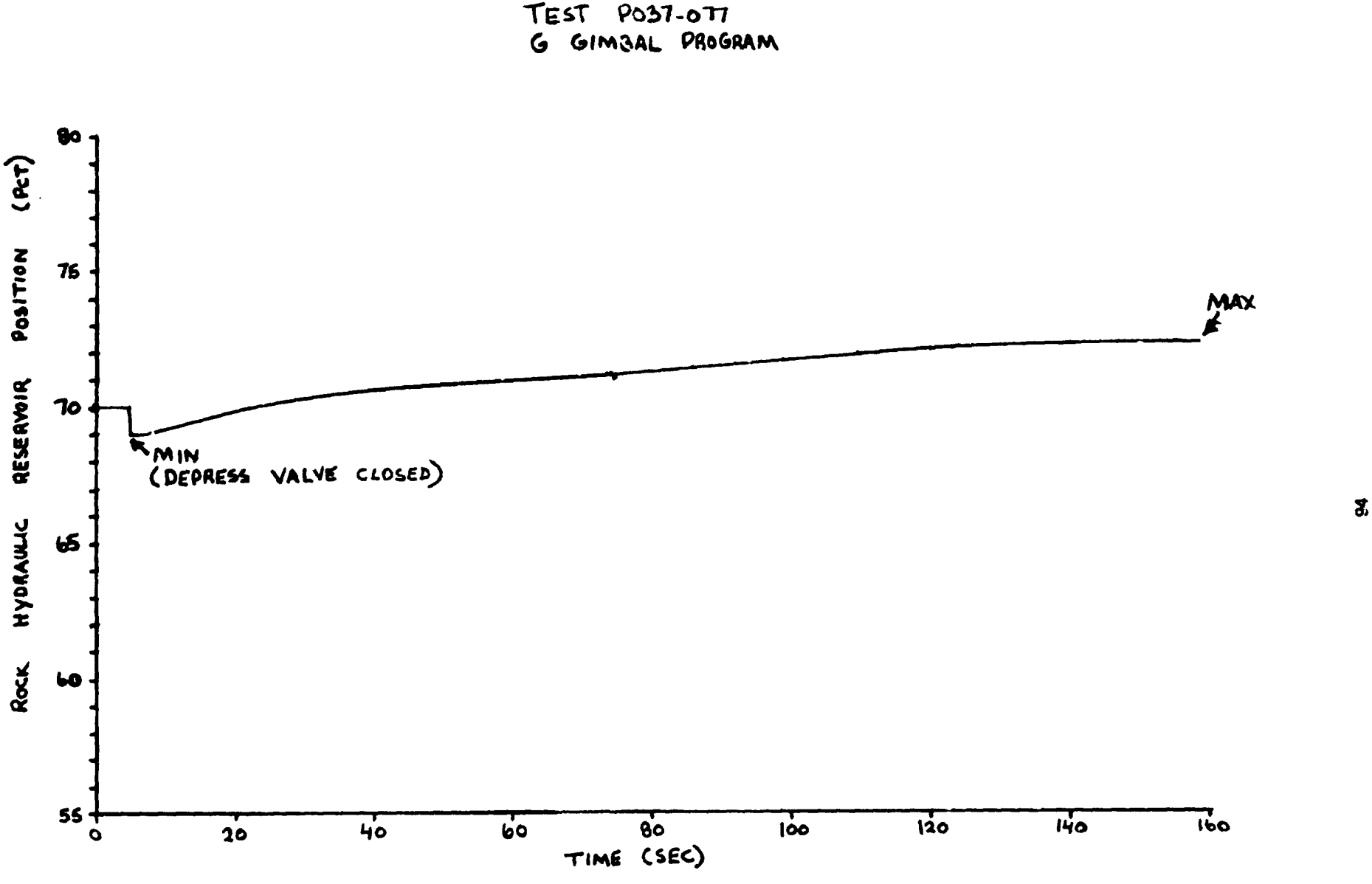

TEST P037-077
G GIMBAL PROGRAM
ROCK HYDRAULIC RESERVOIR POSITION (PCT)
80
75
70
65
60
55
MAX
MIN
(DEPRESS VALVE CLOSED)
0
20
40
60
80
100
120
140
160
TIME (SEC)

FIGURE C–6

TEST P037-077
G GIMBAL PROGRAM

R3

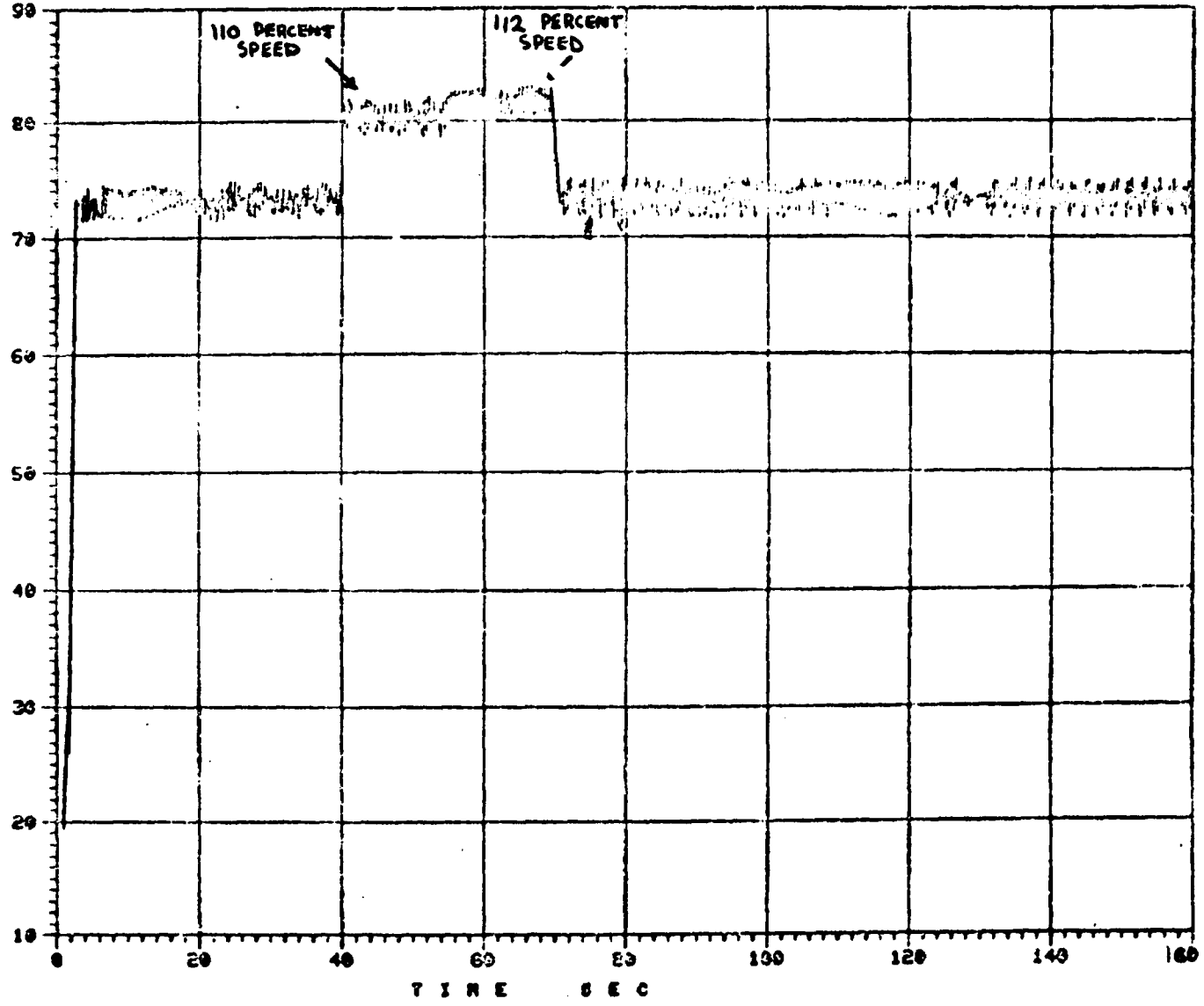


FIGURE C–7

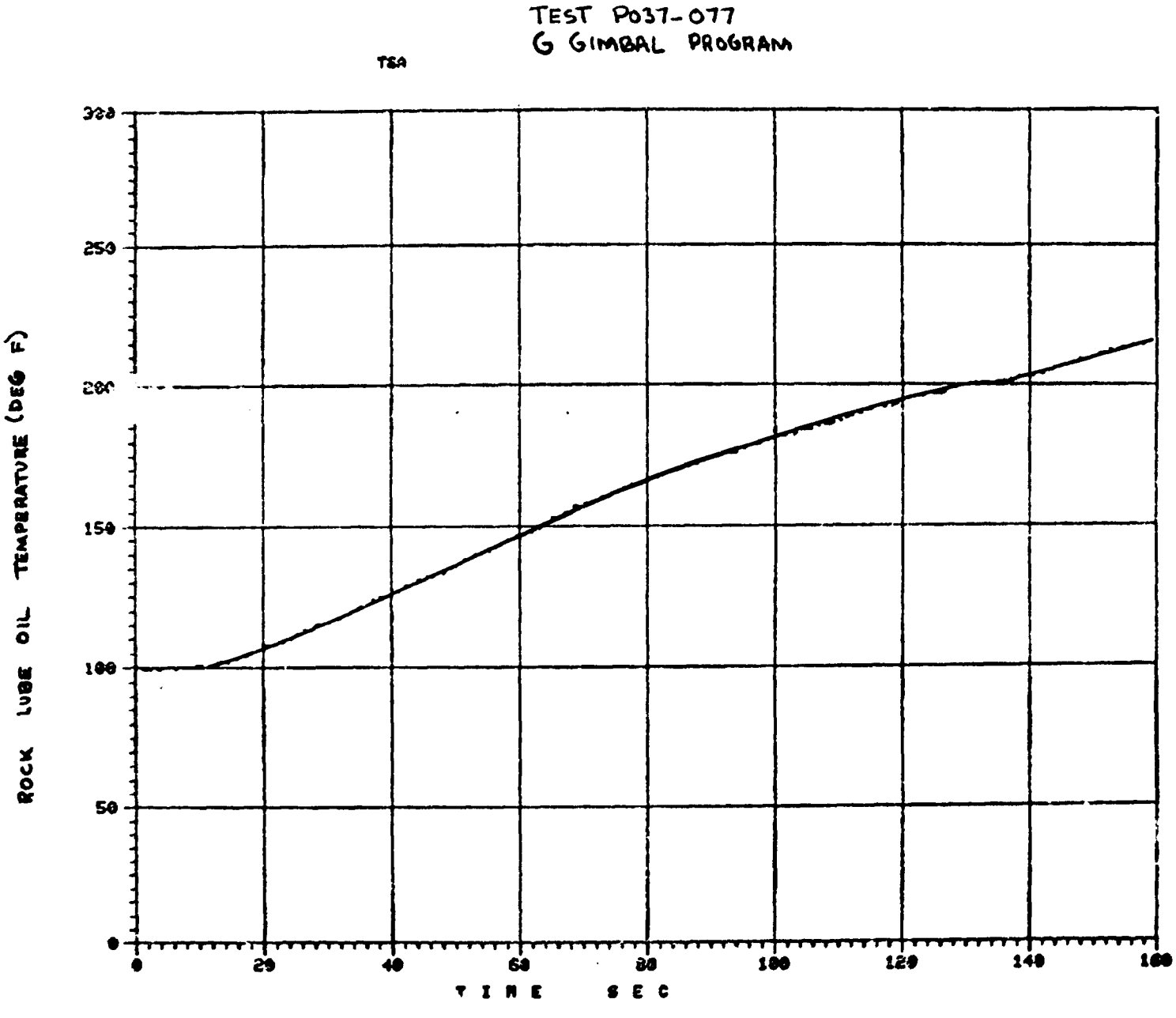

TEST P037-077
G GIMBAL PROGRAM
TSA
ROCK LUBE OIL TEMPERATURE (DEG F)
300
250
200
150
100
50
0
0
20
40
60
80
100
120
140
160
TIME SEC

FIGURE C–8

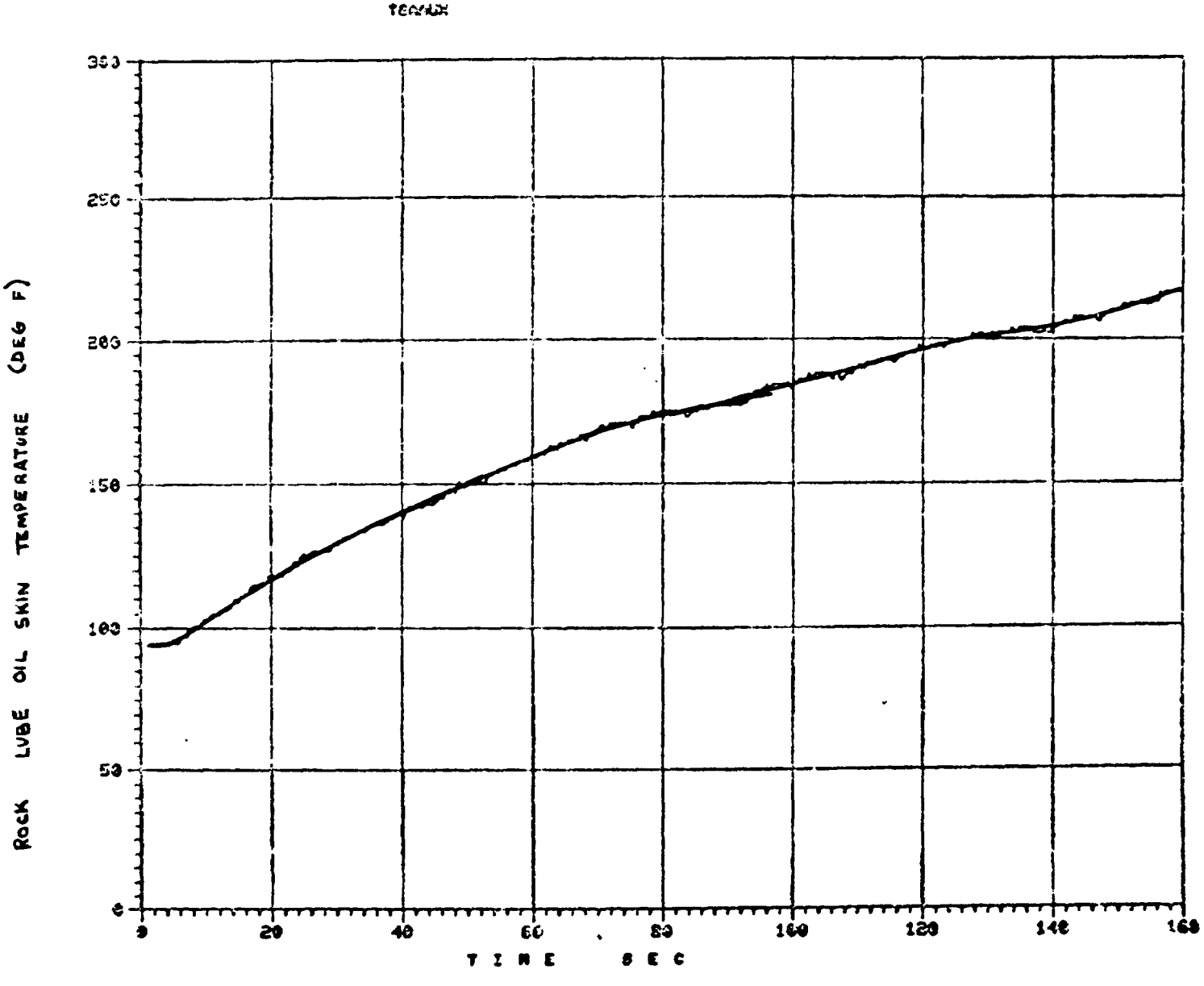

TEST P037-077
G GIMBAL PROGRAM
TEKTRONIX
300
250
200
150
100
50
0
ROCK LUBE OIL SKIN TEMPERATURE (DEG F)
0
20
40
60
80
100
120
140
160
TIME SEC

FIGURE C–9

TEST P037-077
G GIMBAL PROGRAM

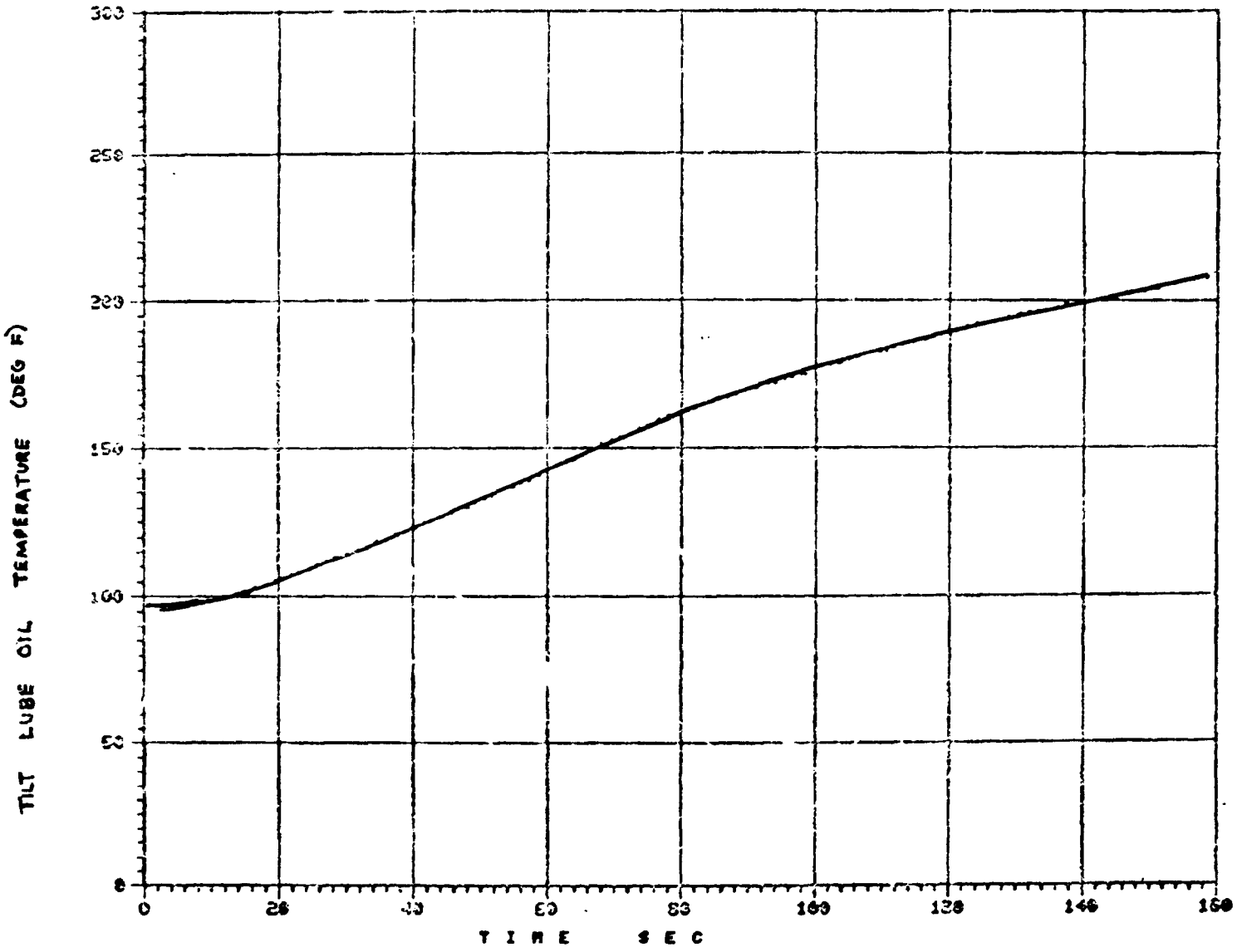


FIGURE C–10

TEST P037-077
G GIMBAL PROGRAM

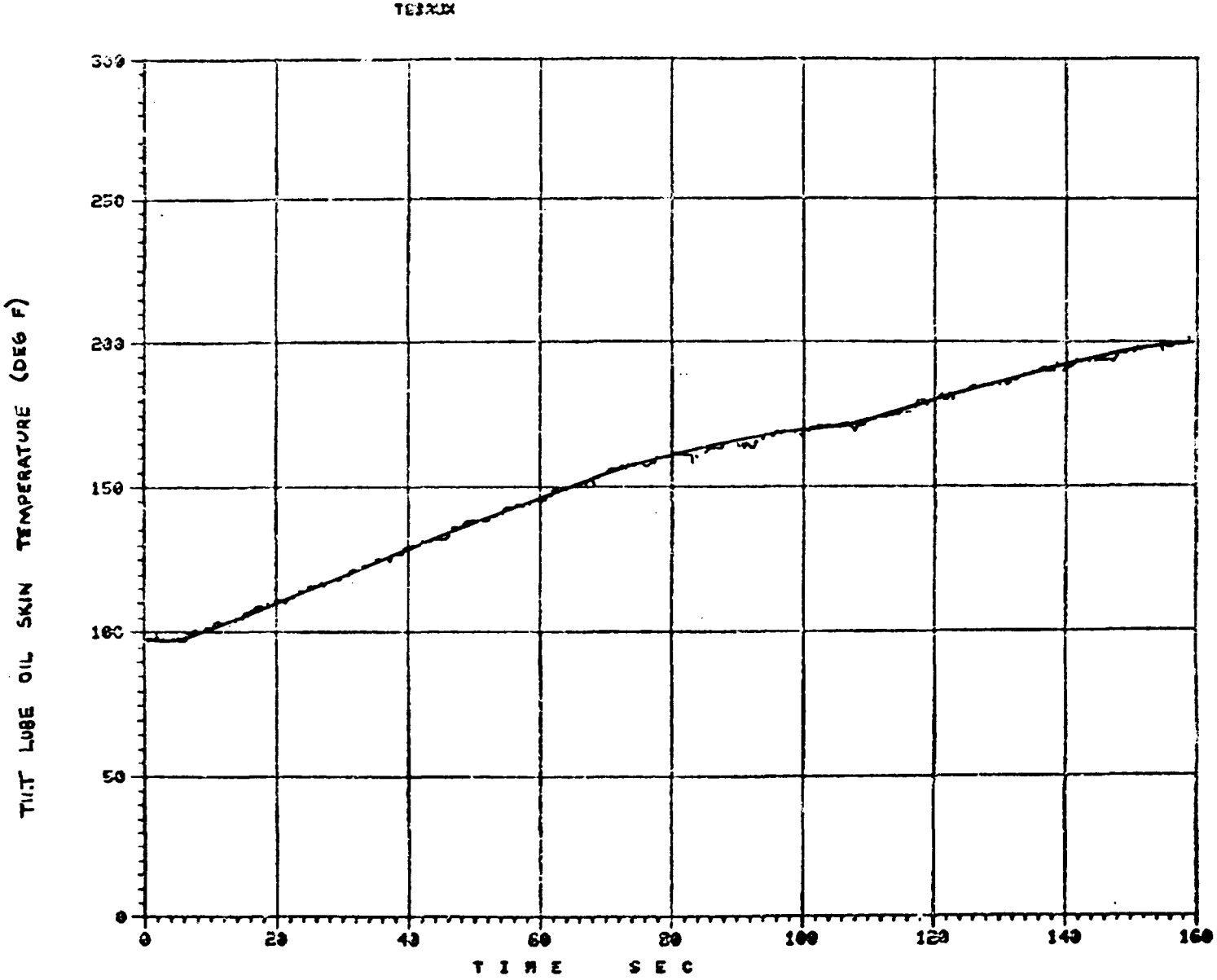


FIGURE C–11

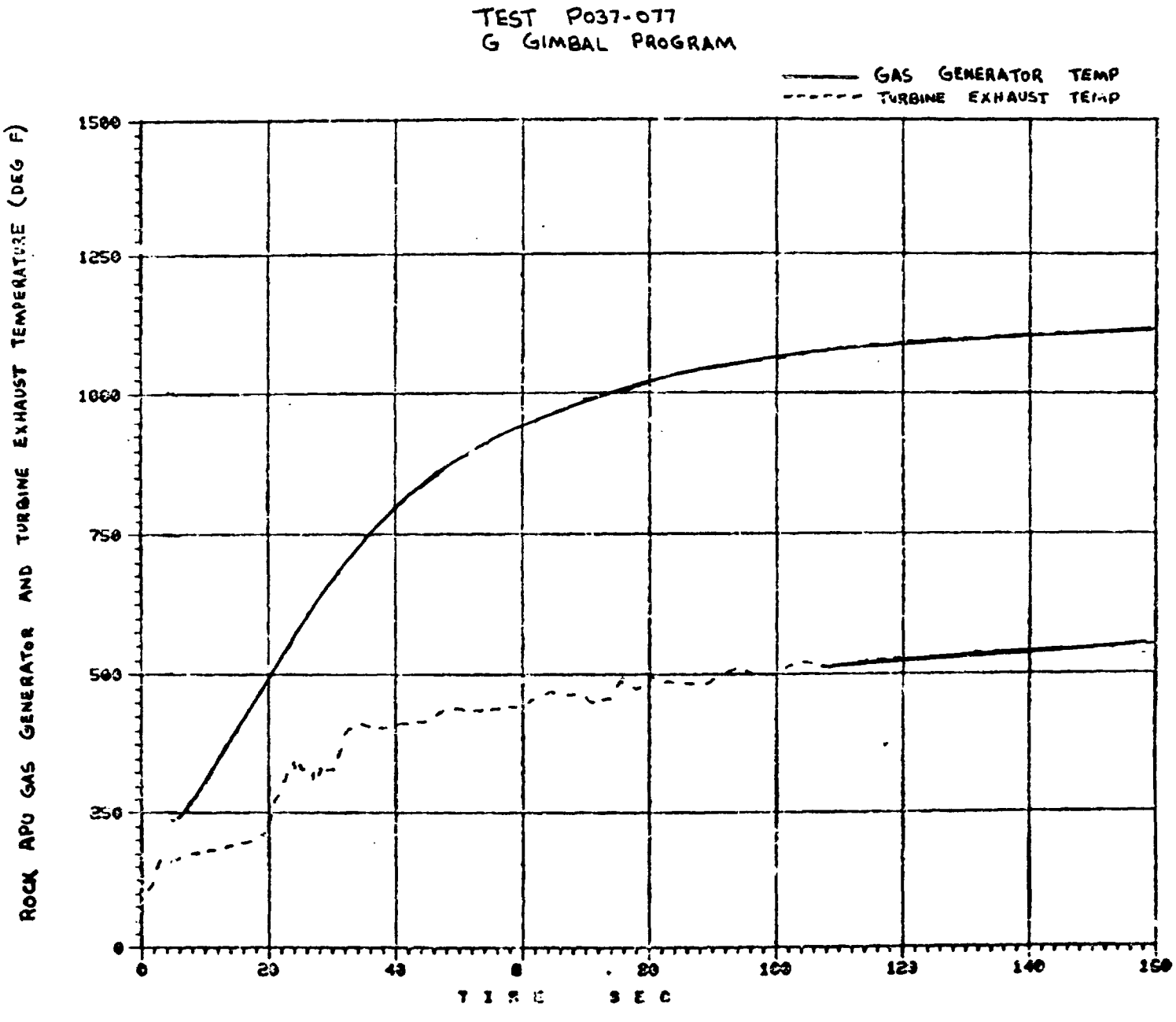

TEST P037-077
G GIMBAL PROGRAM
GAS GENERATOR TEMP
TURBINE EXHAUST TEMP
ROCK APU GAS GENERATOR AND TURBINE EXHAUST TEMPERATURE (DEG F)
1500
1250
1000
750
500
250
0
0
20
40
60
80
100
120
140
160
TIME SEC

FIGURE C–12

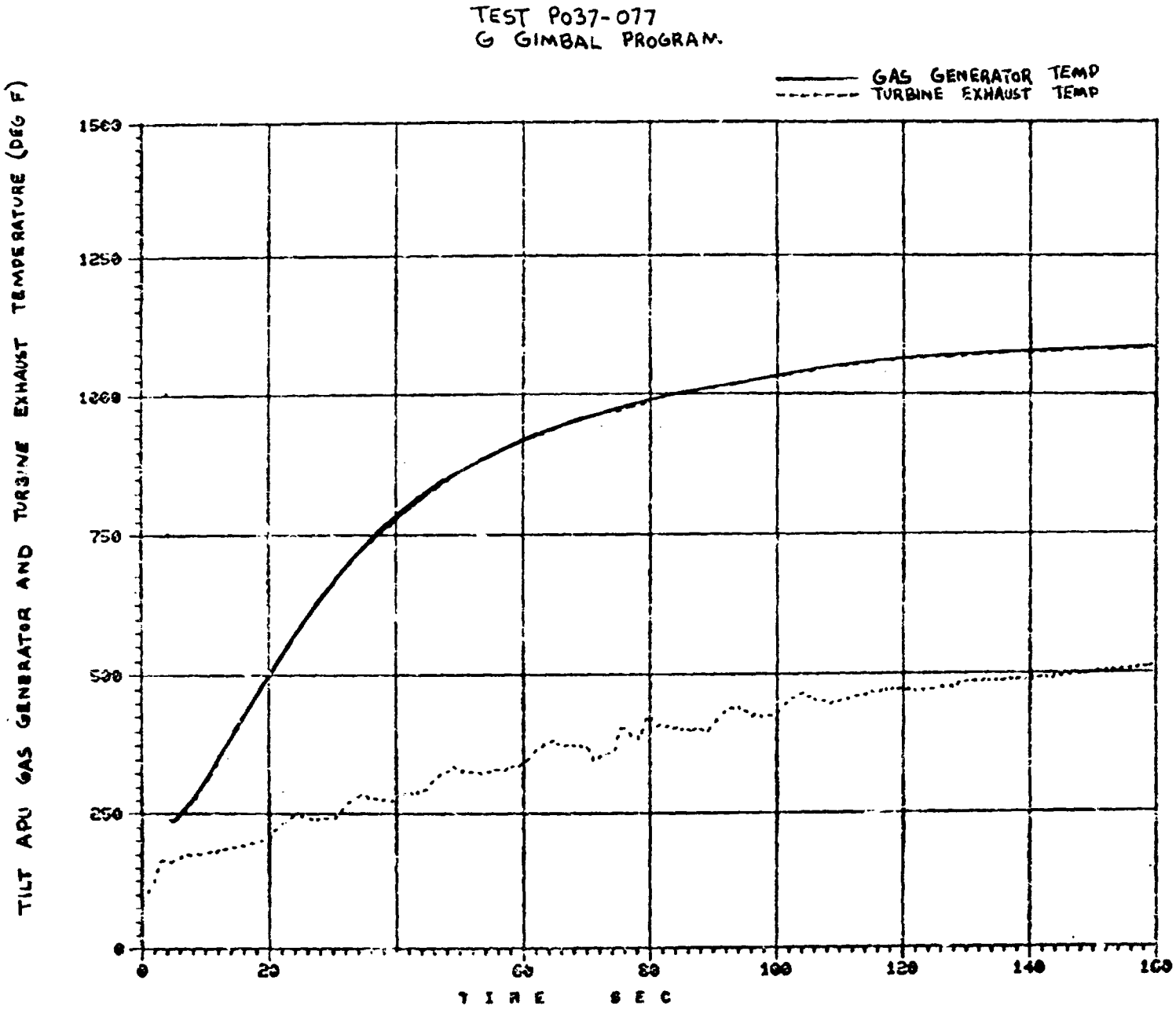

TEST P037-077
G GIMBAL PROGRAM
GAS GENERATOR TEMP
TURBINE EXHAUST TEMP
TILT APU GAS GENERATOR AND TURBINE EXHAUST TEMPERATURE (DEG F)
1500
1250
1000
750
500
250
0
0
20
60
80
100
120
140
160
TIME SEC

FIGURE C–13

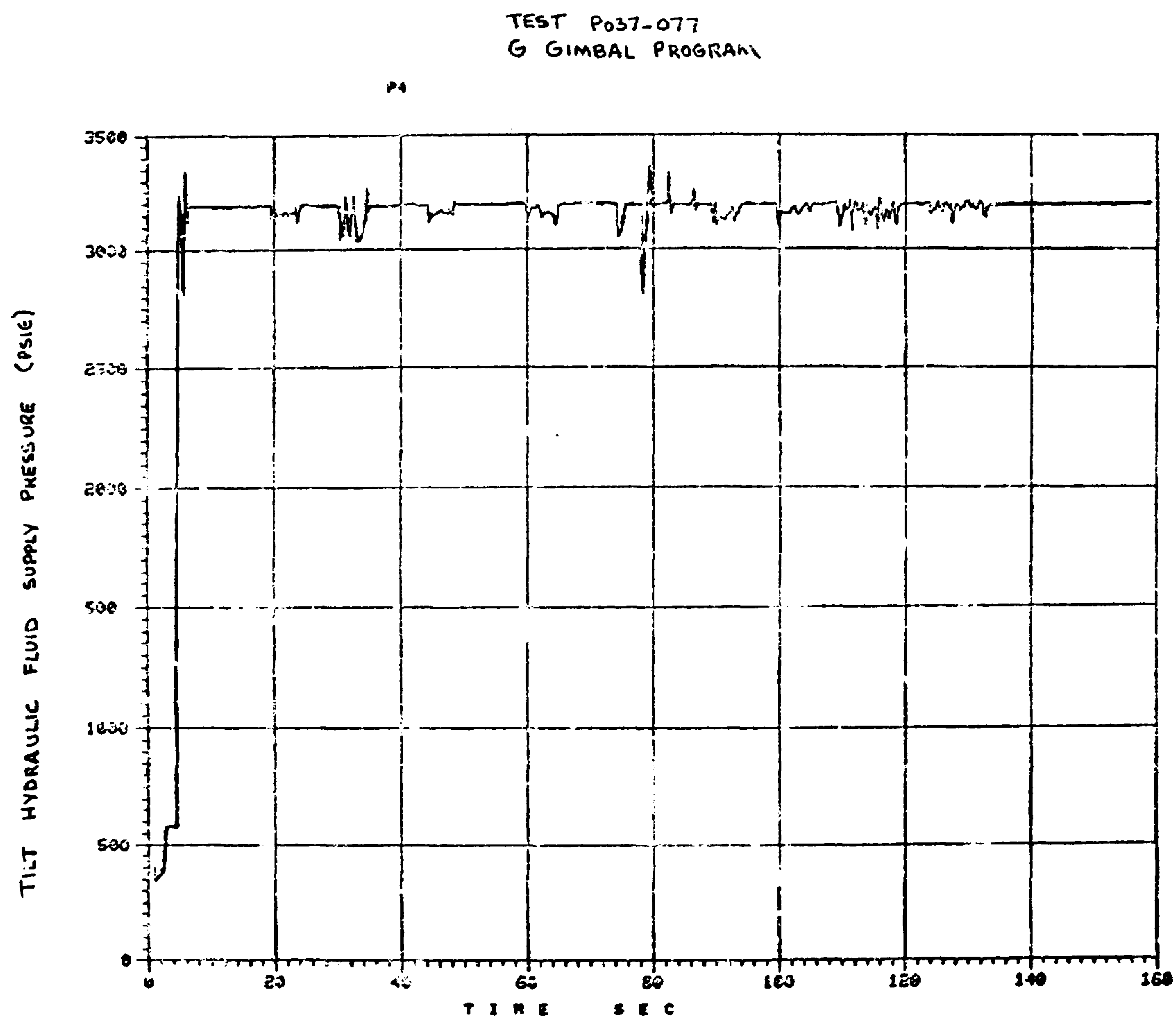


FIGURE C–14

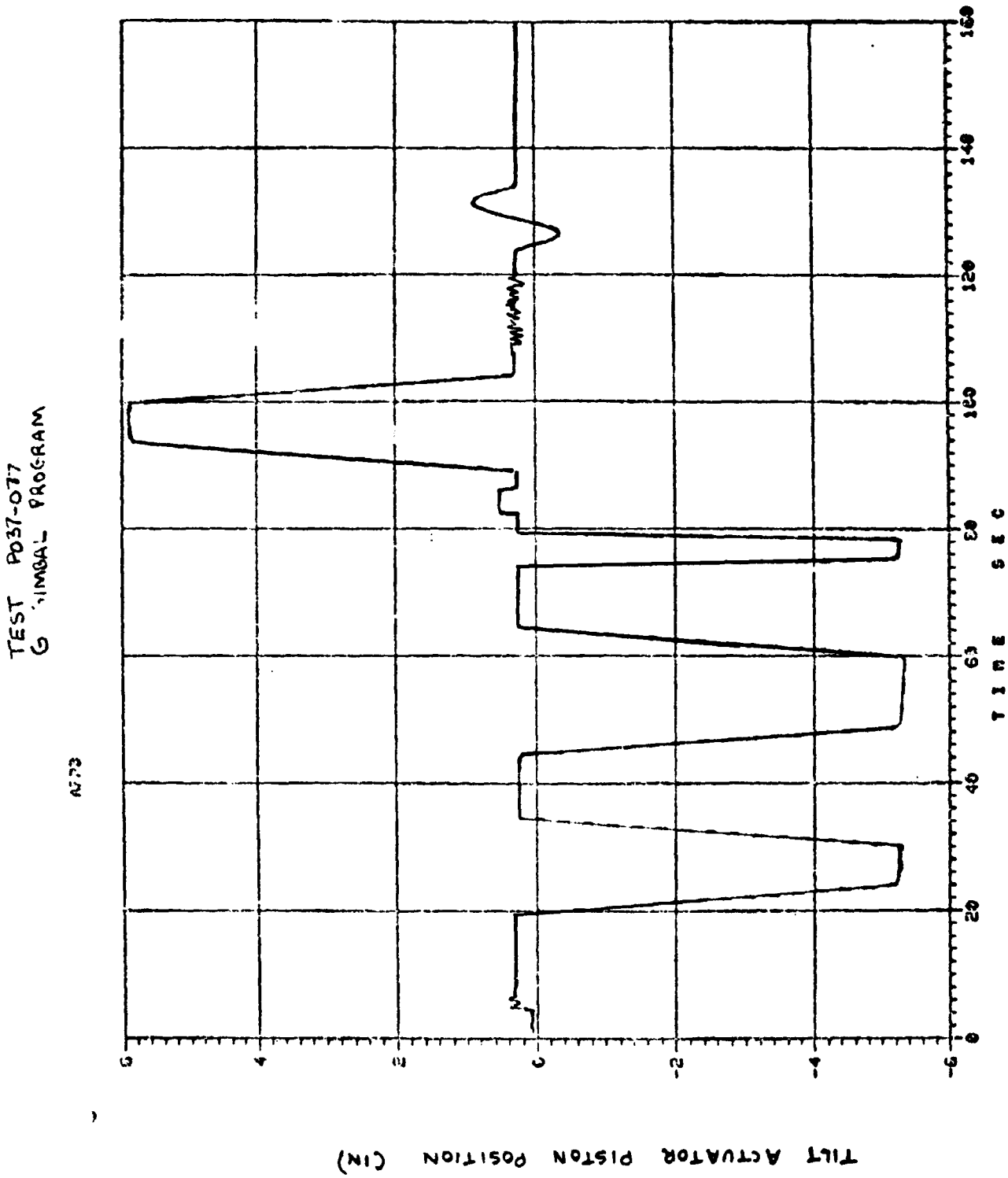

TEST P037-077
GIMBAL PROGRAM
TILT ACTUATOR PISTON POSITION (IN)
TIME SEC
6
4
2
0
-2
-4
-6
0
20
40
60
80
100
120
140
160

FIGURE C-15

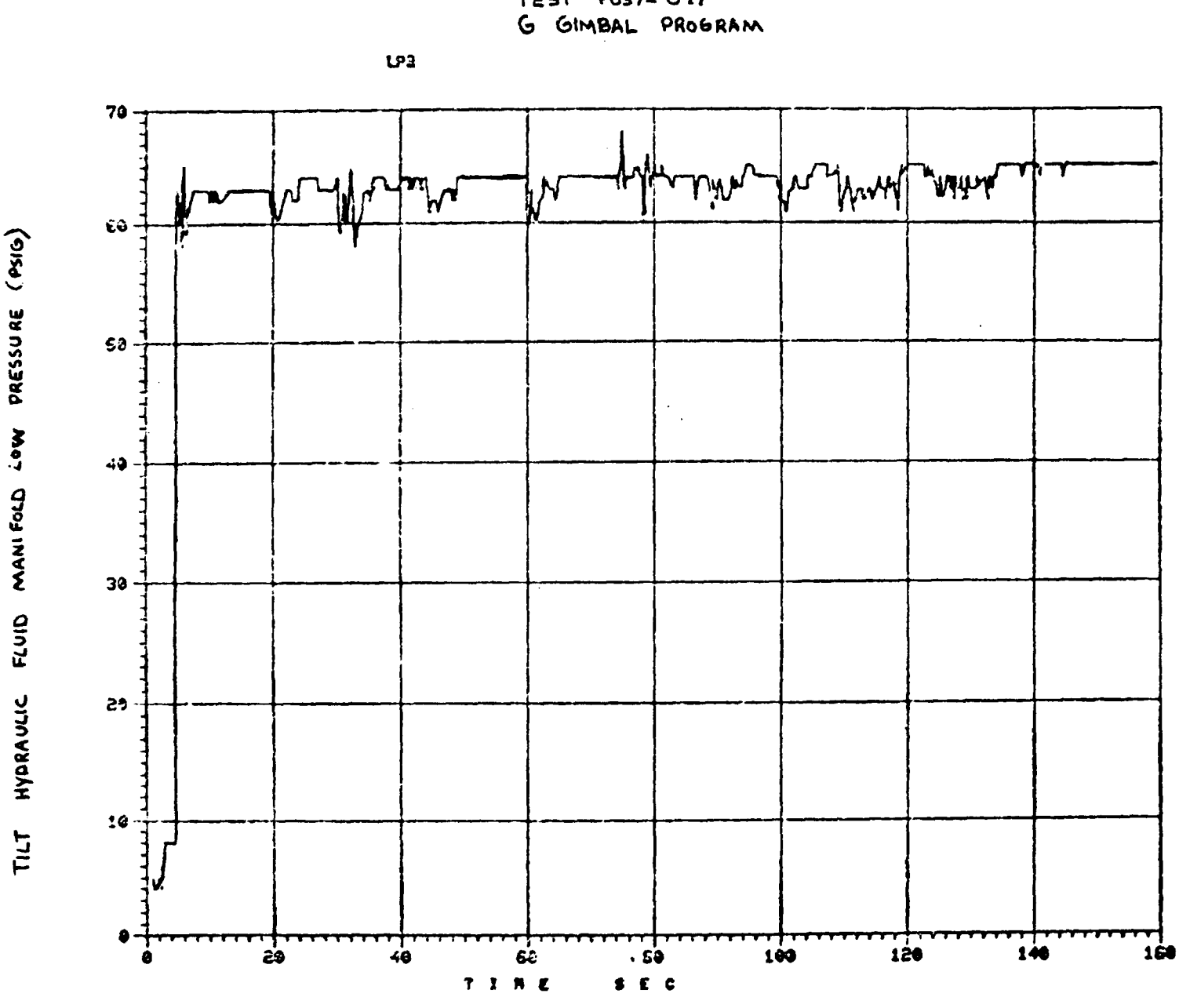

TEST P037-077
G GIMBAL PROGRAM
LP3
TILT HYDRAULIC FLUID MANIFOLD LOW PRESSURE (PSIG)
70
60
50
40
30
20
10
0
0
20
40
60
80
100
120
140
160
TIME SEC

FIGURE C–16

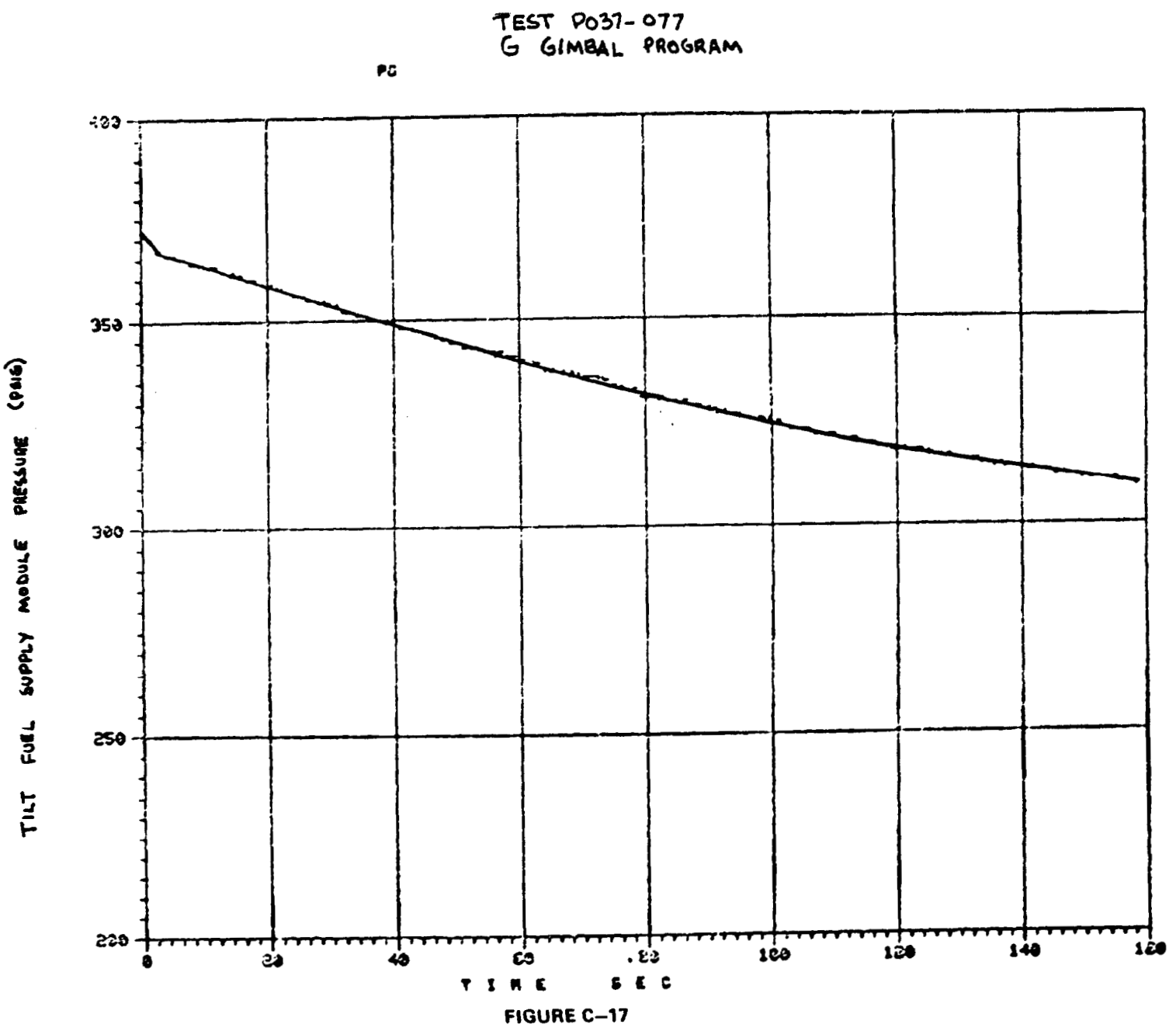

TEST P037-077
G GIMBAL PROGRAM
PC
TILT FUEL SUPPLY MODULE PRESSURE (PSIG)
400
350
300
250
200
0
20
40
60
80
100
120
140
160
TIME SEC

FIGURE C–17

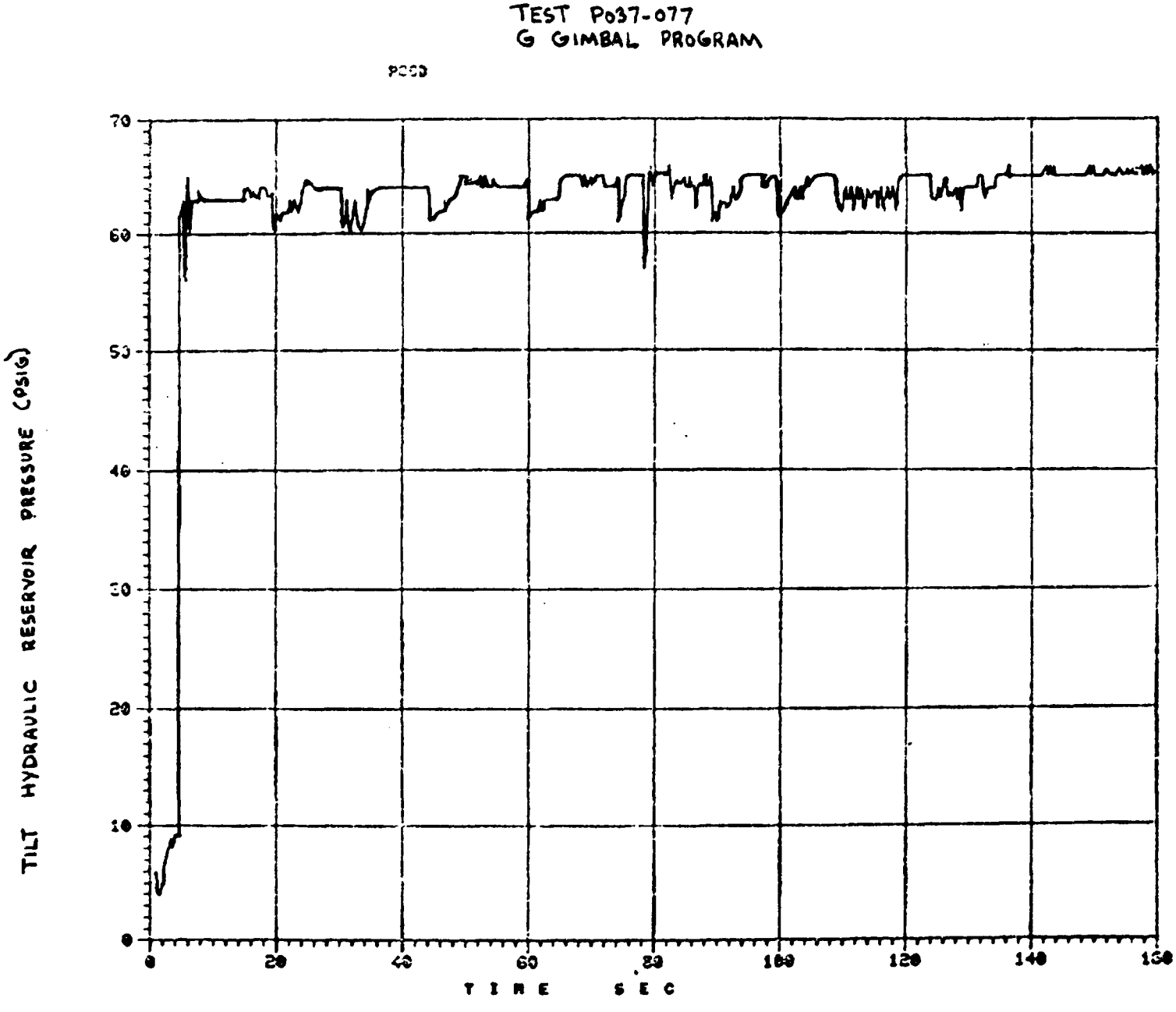

TEST P037-077
G GIMBAL PROGRAM
P000
TILT HYDRAULIC RESERVOIR PRESSURE (PSIG)
70
60
50
40
30
20
10
0
0
20
40
60
80
100
120
140
160
TIME SEC

FIGURE C–18

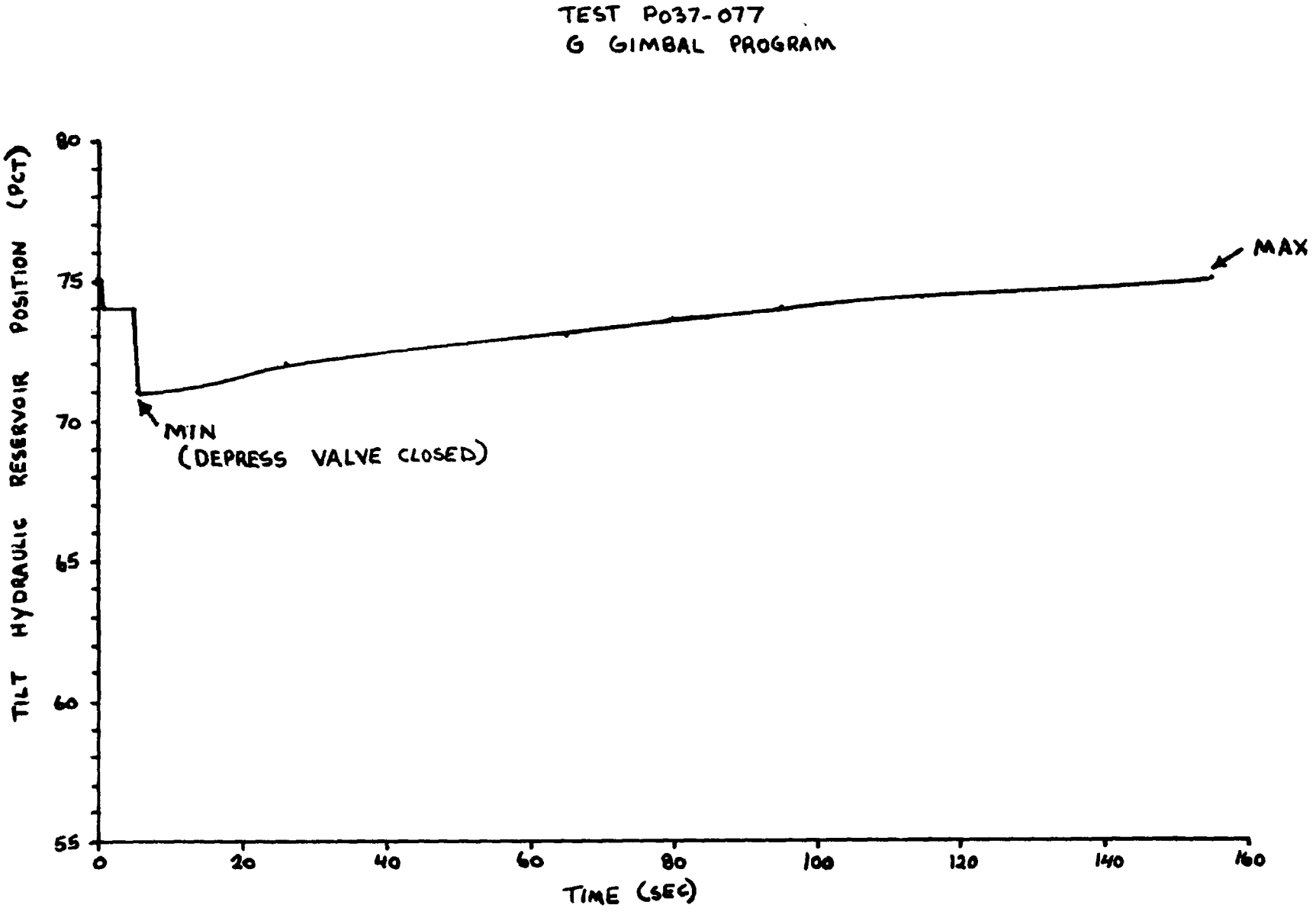

TEST P037-077
G GIMBAL PROGRAM
TILT HYDRAULIC RESERVOIR POSITION (PCT)
80
75
70
65
60
55
MAX
MIN
(DEPRESS VALVE CLOSED)
0
20
40
60
80
100
120
140
160
TIME (SEC)

FIGURE C–19

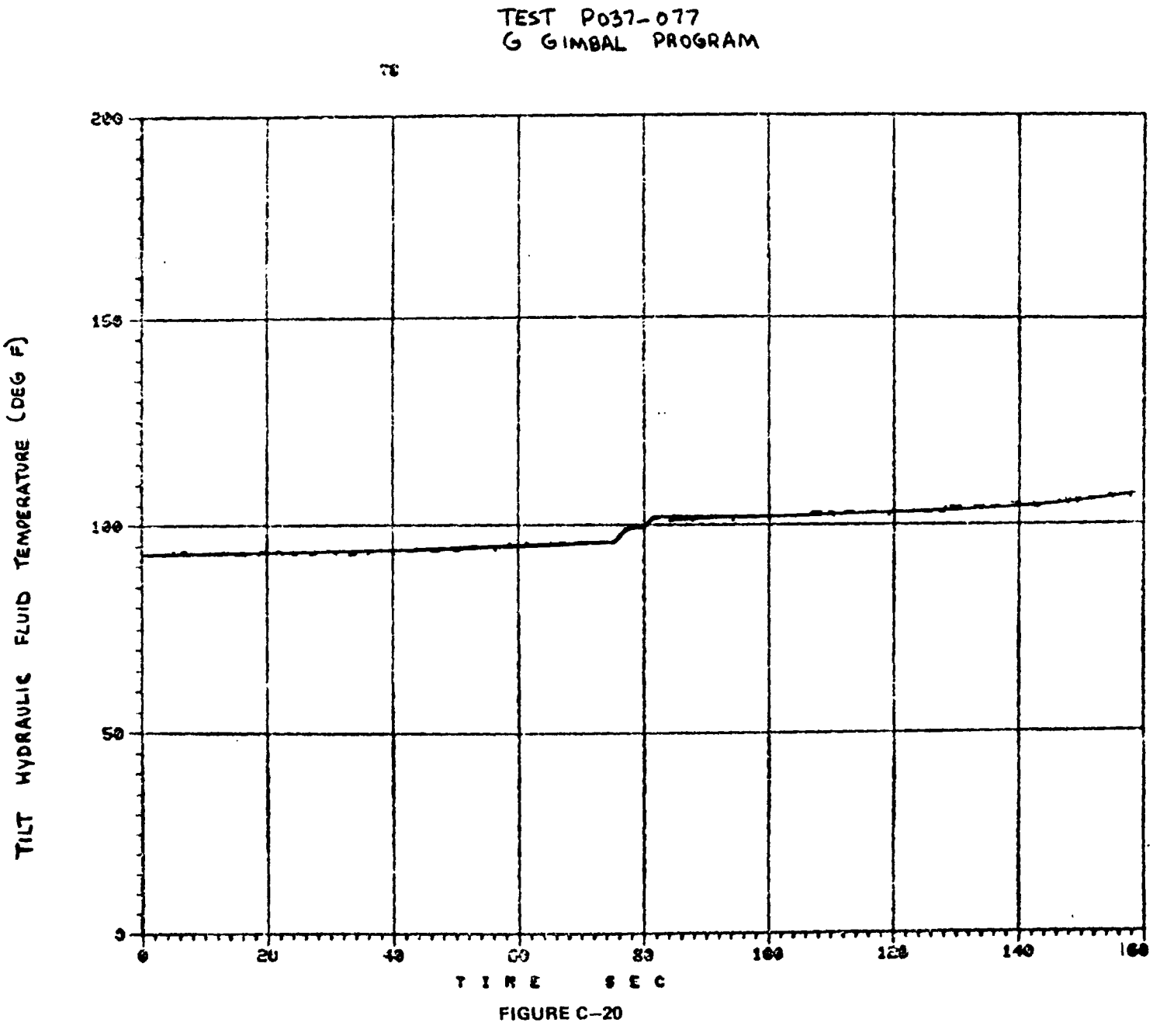
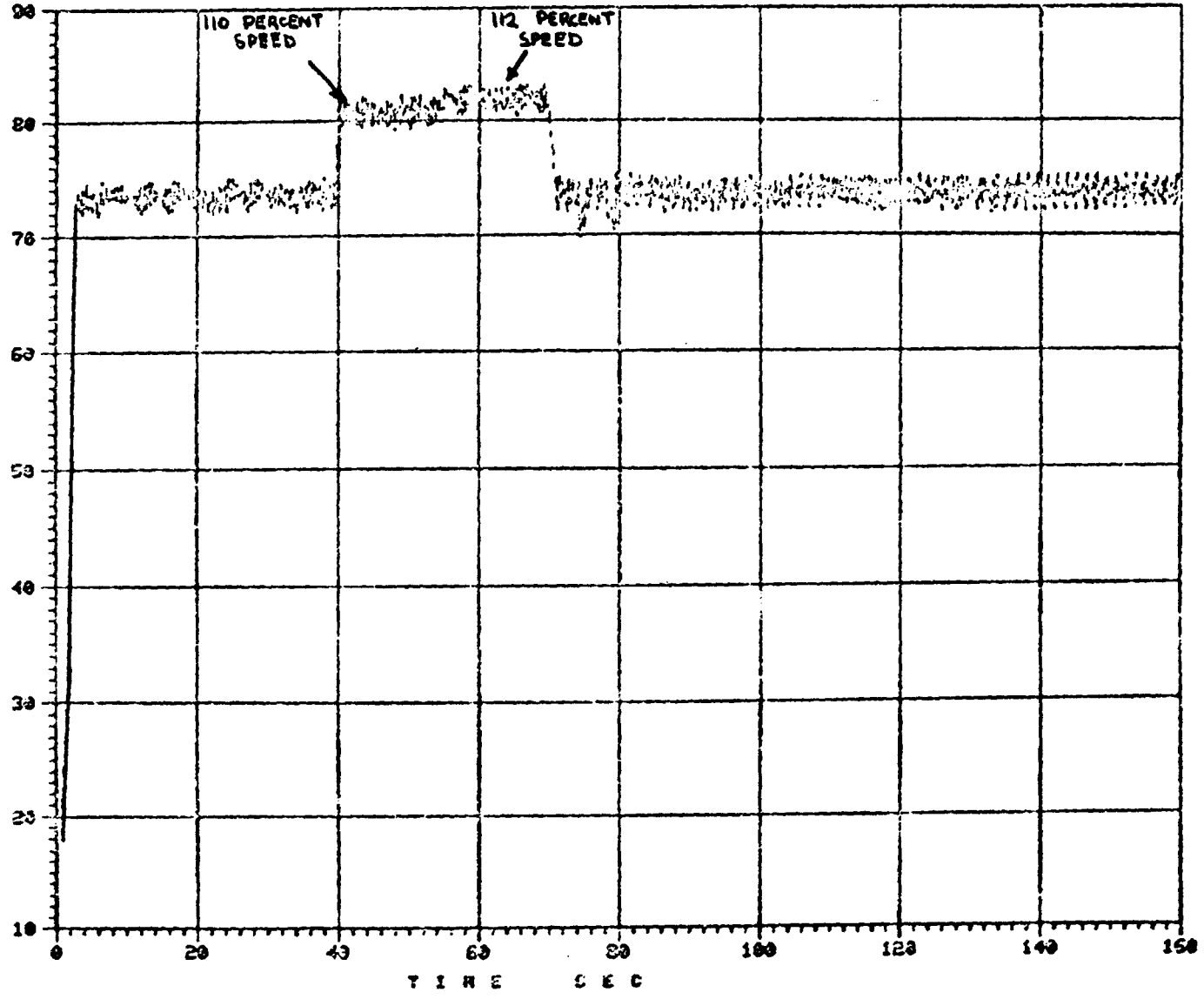

TEST P037-077
G GIMBAL PROGRAM
TILT HYDRAULIC FLUID TEMPERATURE (DEG F)
200
150
100
50
0
0
20
40
60
80
100
120
140
160
TIME SEC

FIGURE C–20

TEST P037-077
G GIMBAL PROGRAM

R7

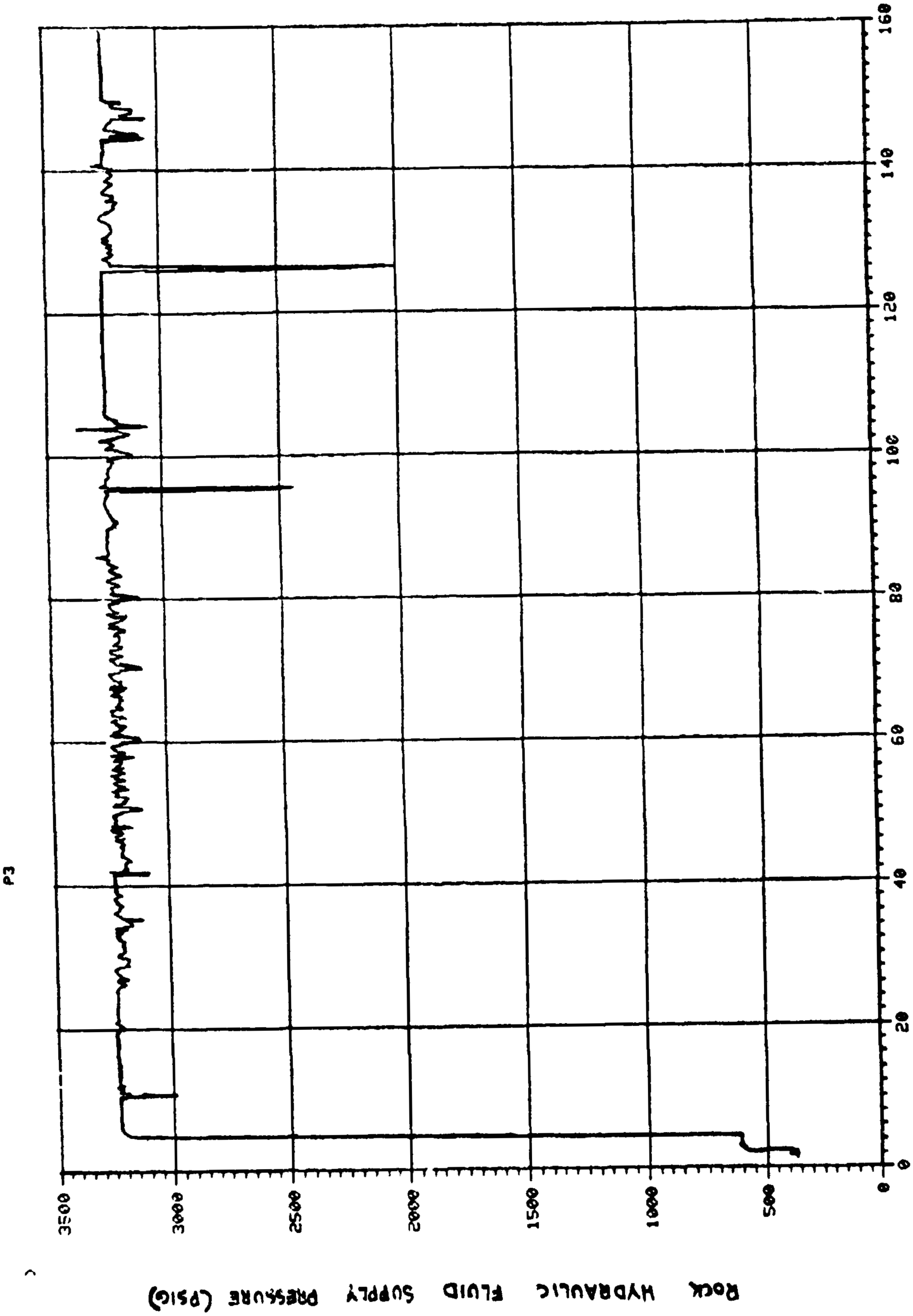


601

FIGURE C–21

TEST P037-111

TEST Po37-111
N* GIMBAL PROGRAM



ROCK HYDRAULIC FLUID SUPPLY PRESSURE (PSIG)

FIGURE C-22

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OF POOR QUALITY

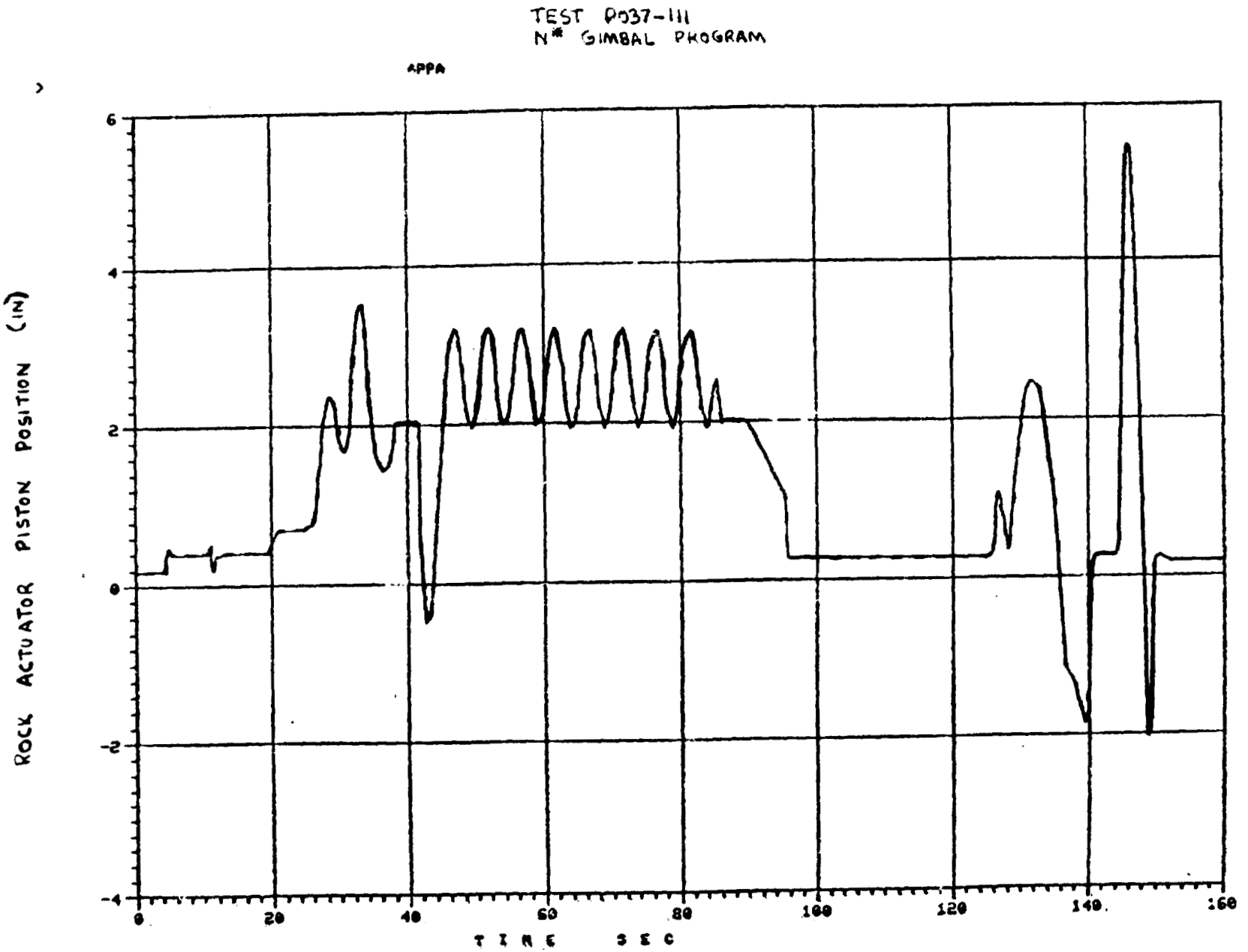

TEST P037-III
N* GIMBAL PROGRAM
APPA
ROCK ACTUATOR PISTON POSITION (IN)
6
4
2
0
-2
-4
0
20
40
60
80
100
120
140
160
TIME SEC

FIGURE C–23

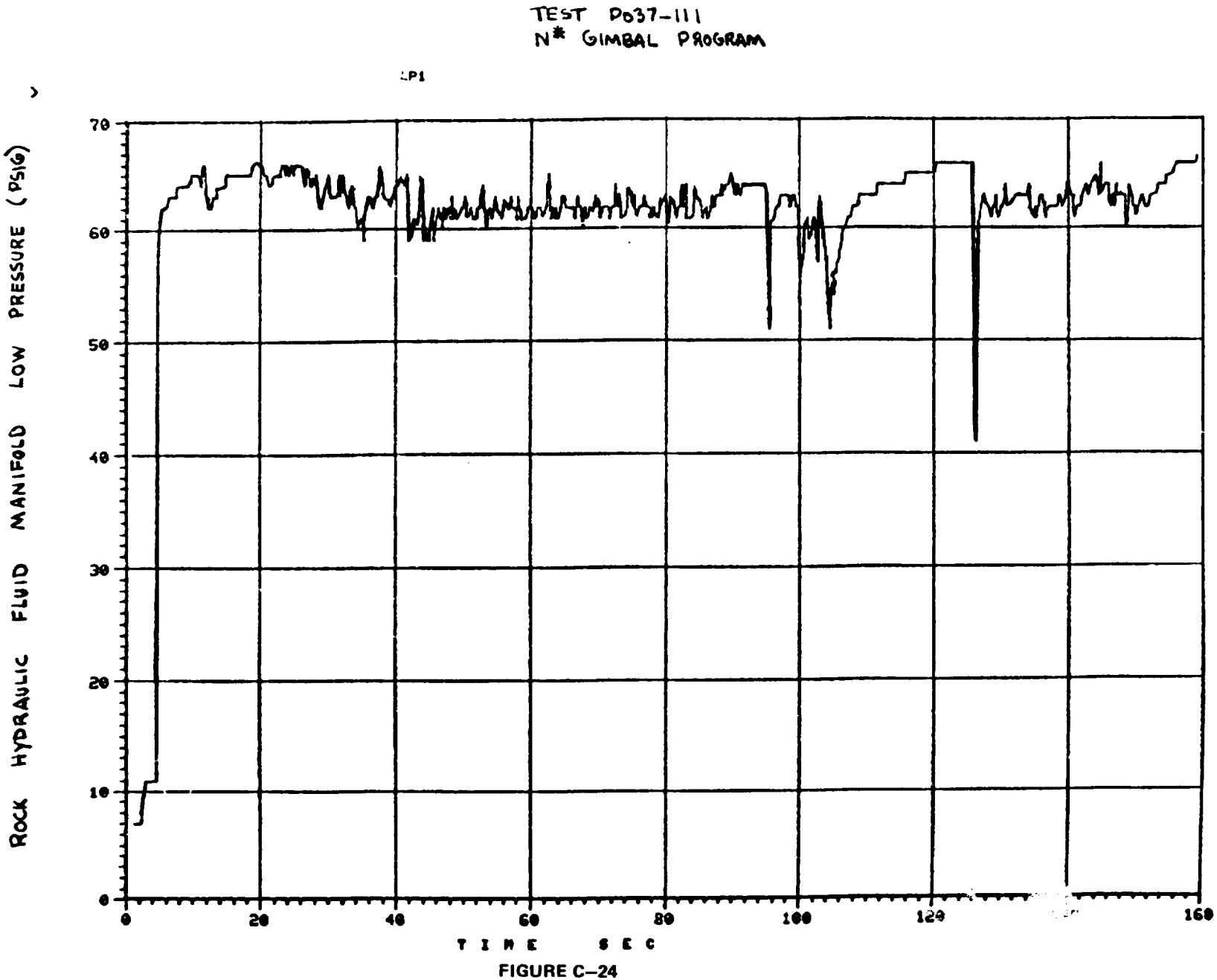

TEST P037-111
N* GIMBAL PROGRAM
LP1
ROCK HYDRAULIC FLUID MANIFOLD LOW PRESSURE (PSIG)
70
60
50
40
30
20
10
0
0
20
40
60
80
100
120
160
TIME SEC

FIGURE C–24

TEST P037-111
N* GIMBAL PROGRAM

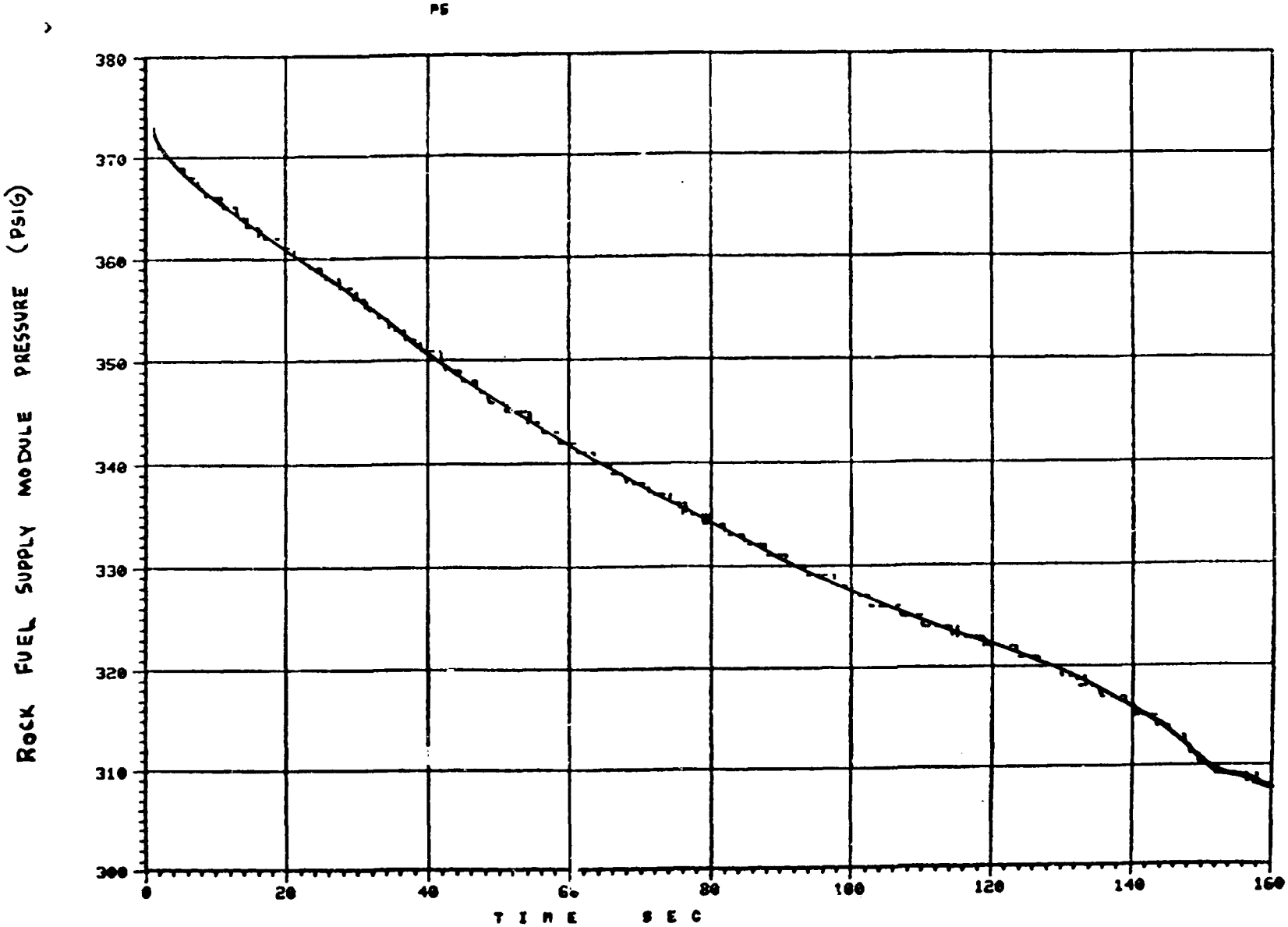


FIGURE C-25

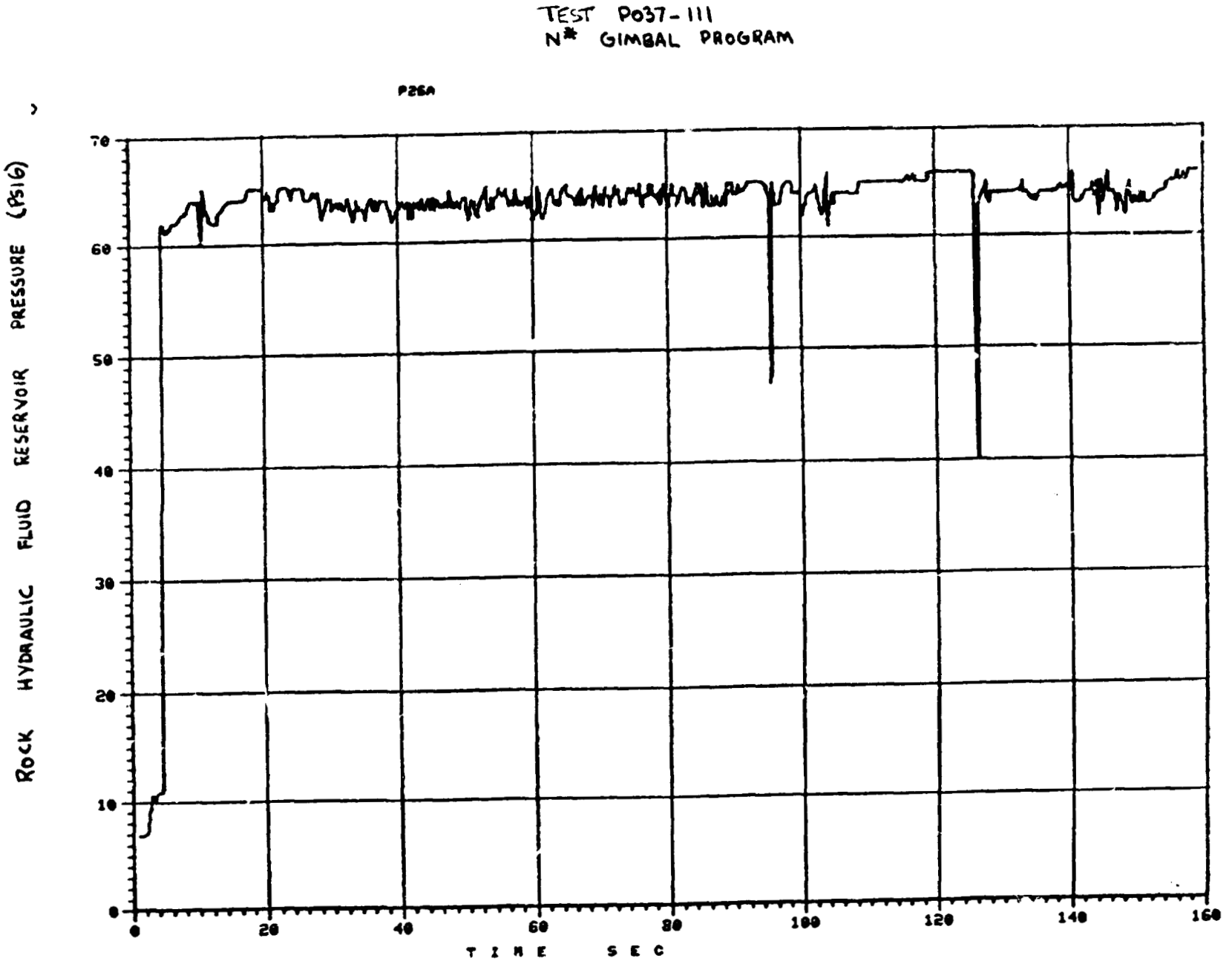

TEST P037-111
N* GIMBAL PROGRAM
P26A
ROCK HYDRAULIC FLUID RESERVOIR PRESSURE (PSIG)
70
60
50
40
30
20
10
0
0
20
40
60
80
100
120
140
160
T I M E S E C

FIGURE C–26

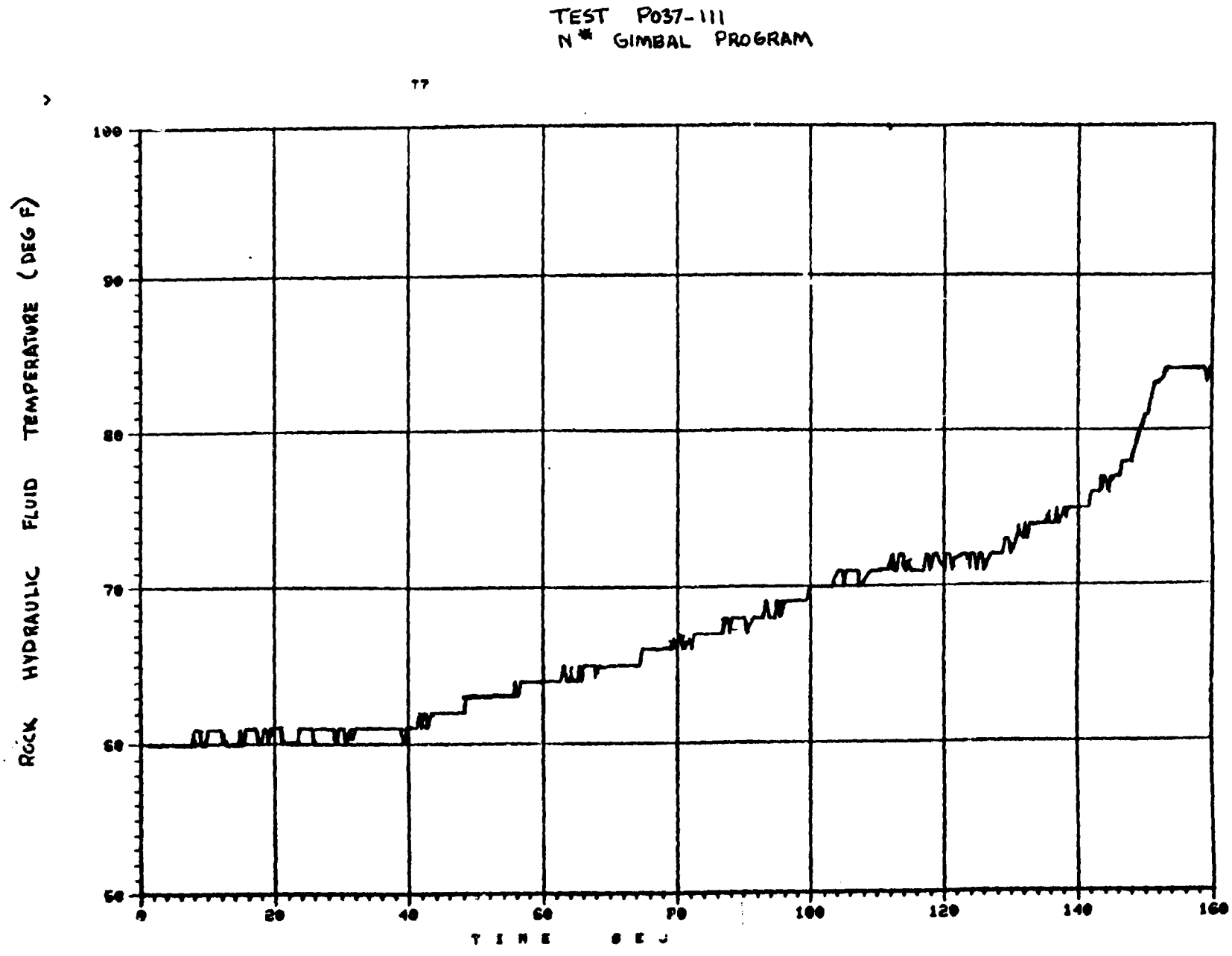

TEST P037-111
N* GIMBAL PROGRAM
77
ROCK HYDRAULIC FLUID TEMPERATURE (DEG F)
100
90
80
70
60
50
0
20
40
60
80
100
120
140
160
TIME SEC

FIGURE C–27

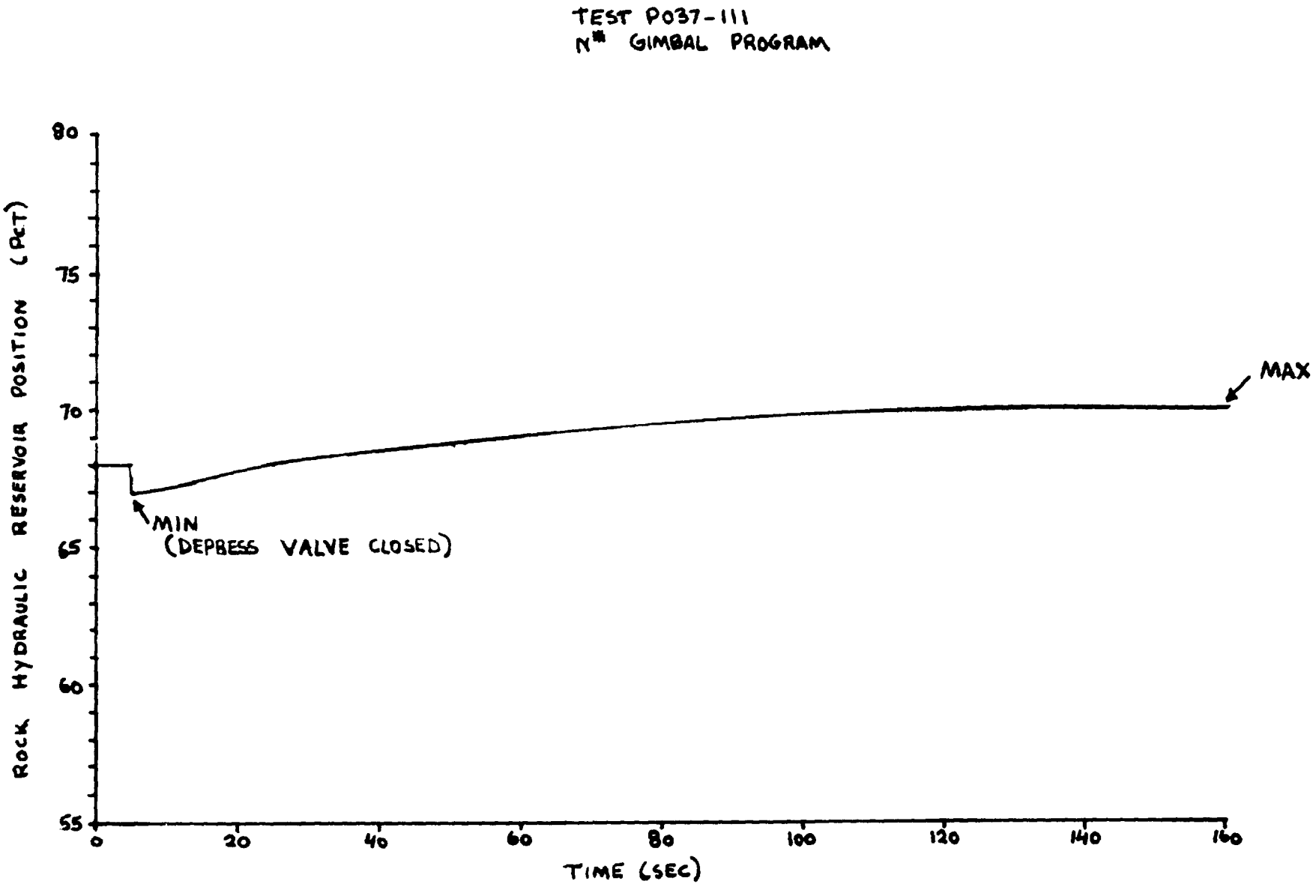

TEST P037-111
N* GIMBAL PROGRAM
ROCK HYDRAULIC RESERVOIR POSITION (PCT)
80
75
70
65
60
55
0
20
40
60
80
100
120
140
160
TIME (SEC)
MAX
MIN
(DEPRESS VALVE CLOSED)

FIGURE C-28

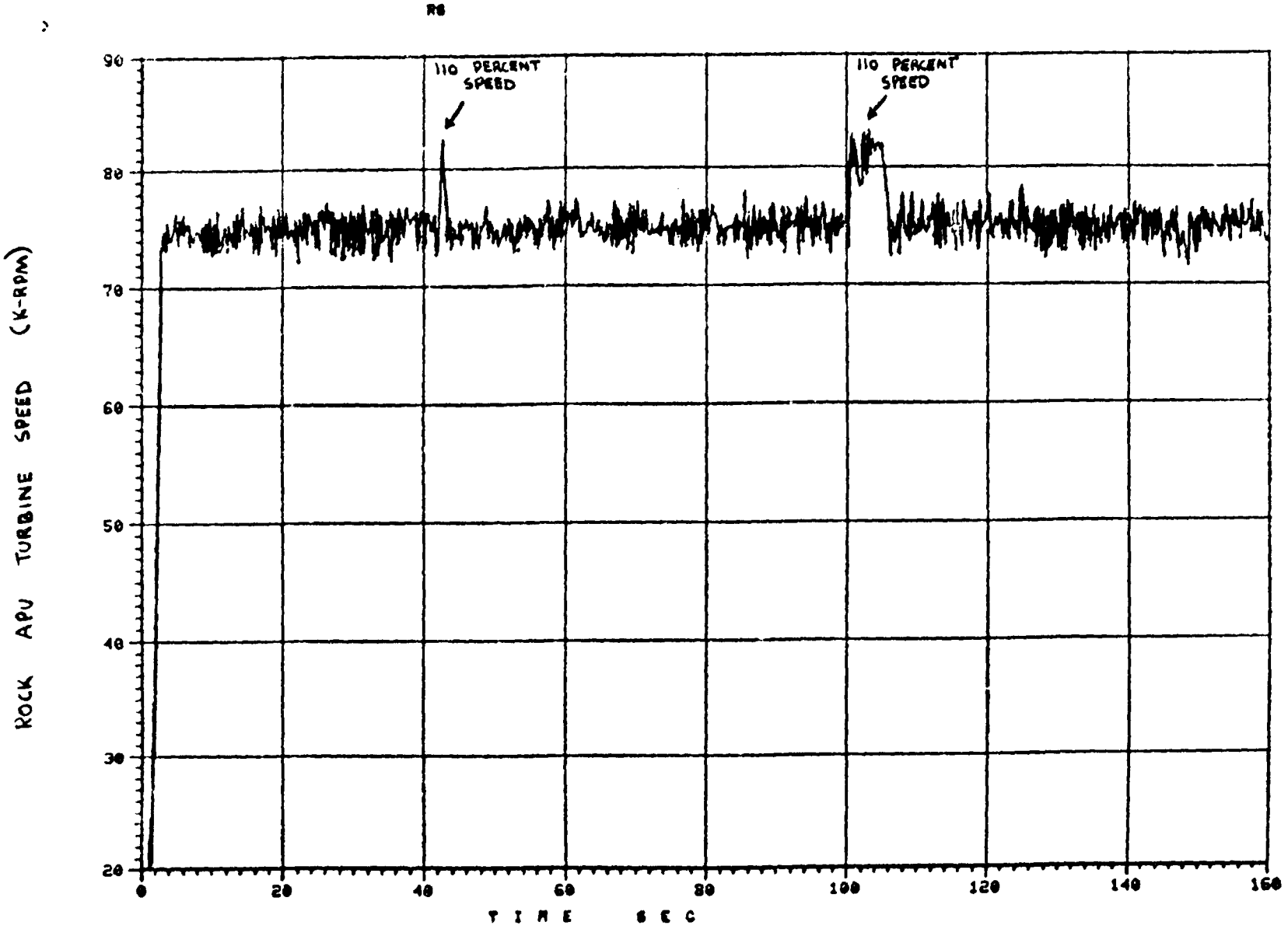

TEST P037-111
N* GIMBAL PROGRAM
R8
110 PERCENT SPEED
110 PERCENT SPEED
ROCK APU TURBINE SPEED (K-RPM)
90
80
70
60
50
40
30
20
0
20
40
60
80
100
120
140
160
T I M E S E C

FIGURE C–29

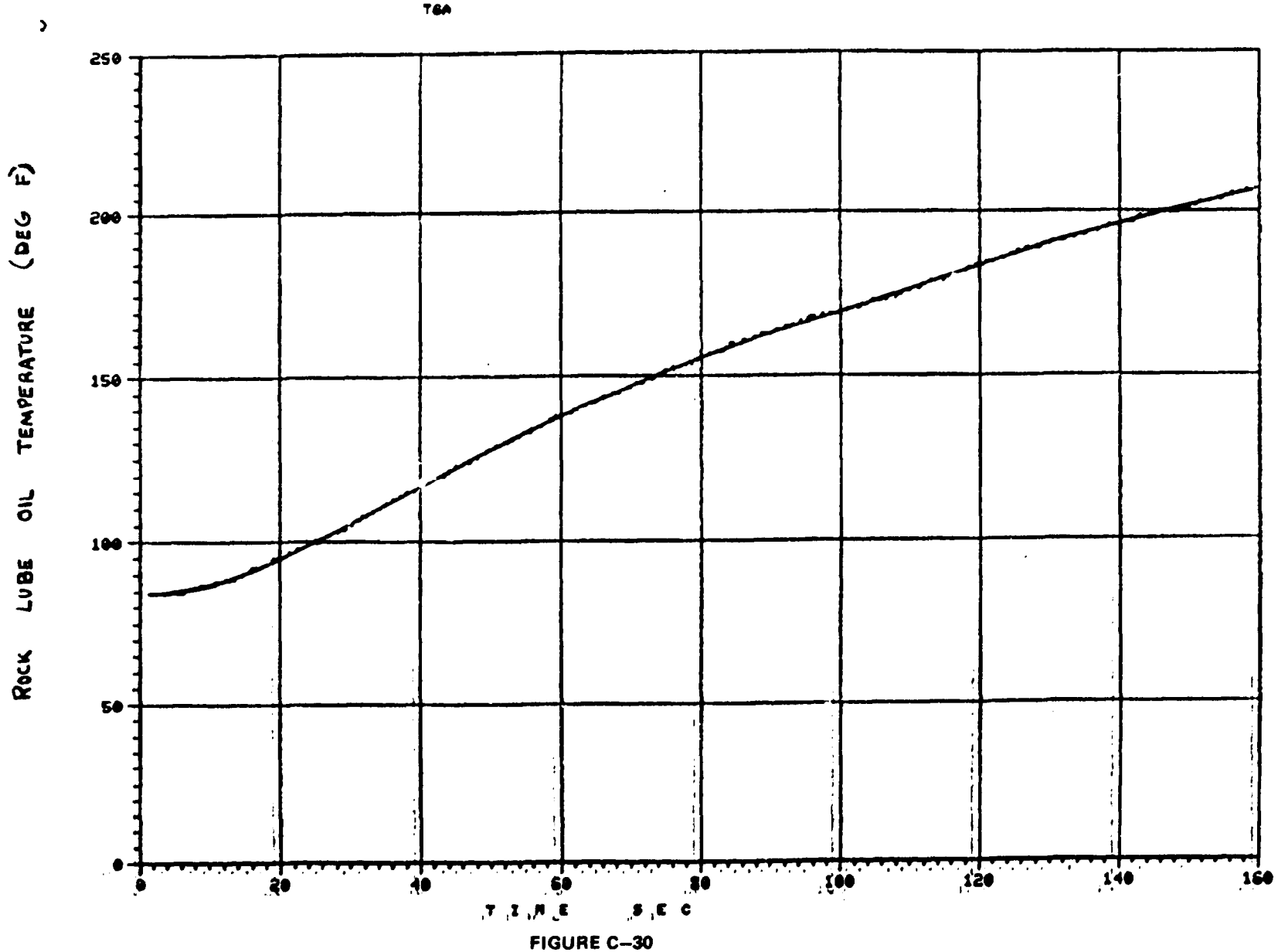

TEST P037-111
N* GIMBAL PROGRAM
T6A
ROCK LUBE OIL TEMPERATURE (DEG F)
250
200
150
100
50
0
0
20
40
60
80
100
120
140
160
TIME SEC

FIGURE C–30

TEST P037-111
N* GIMBAL PROGRAM

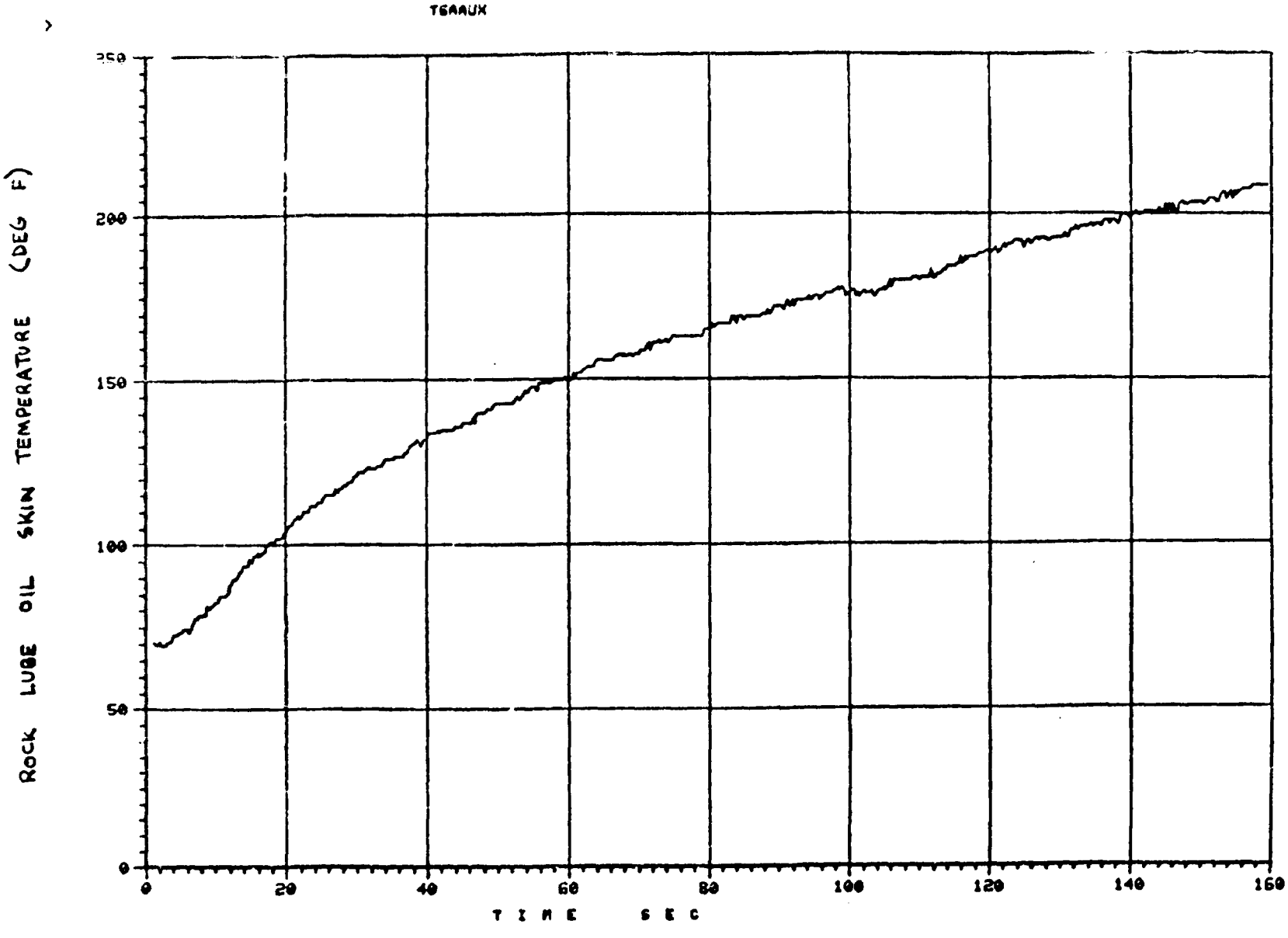


FIGURE C–31

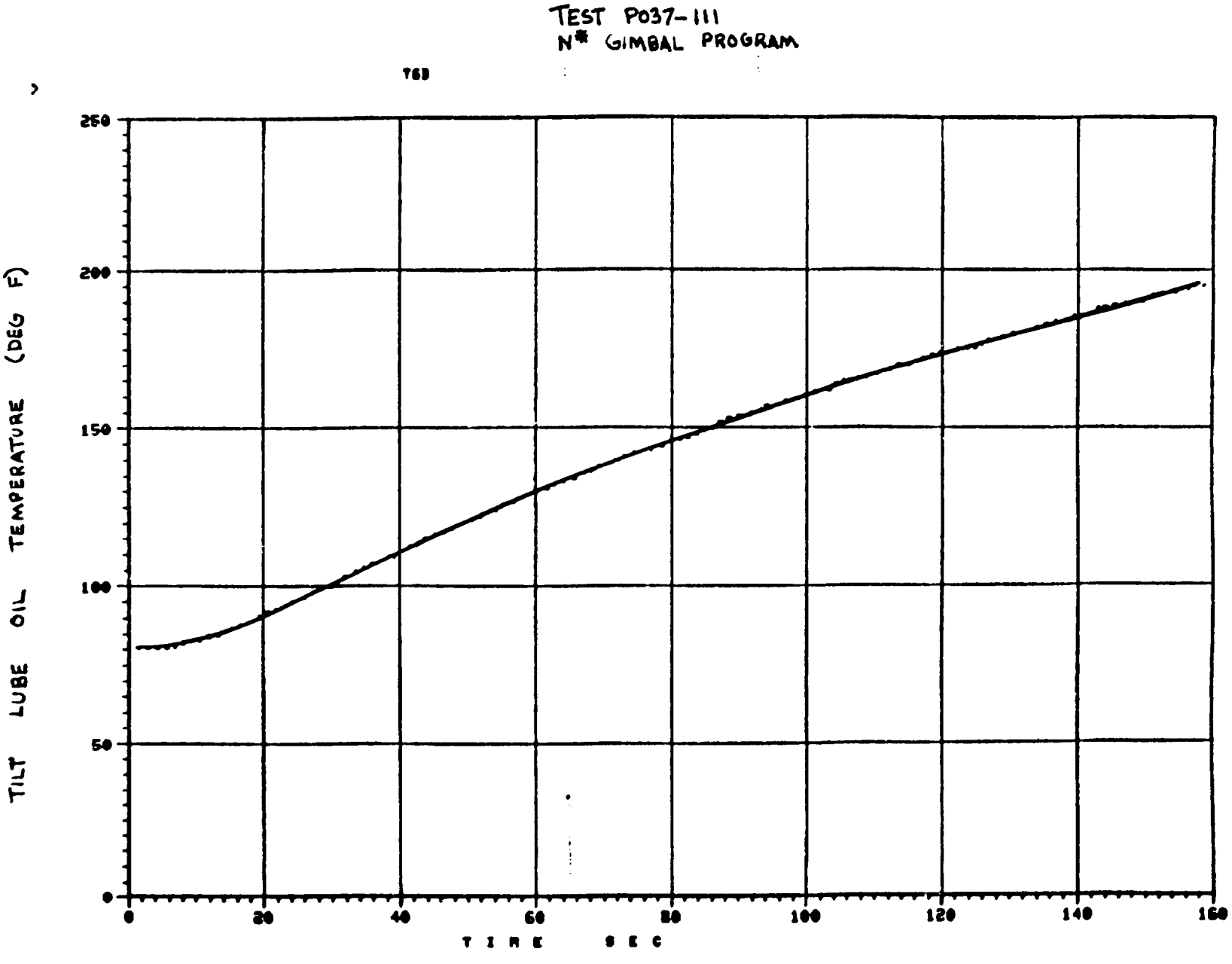

TEST P037-111
N* GIMBAL PROGRAM
TGB
TILT LUBE OIL TEMPERATURE (DEG F)
250
200
150
100
50
0
0
20
40
60
80
100
120
140
160
TIME SEC

FIGURE C–32

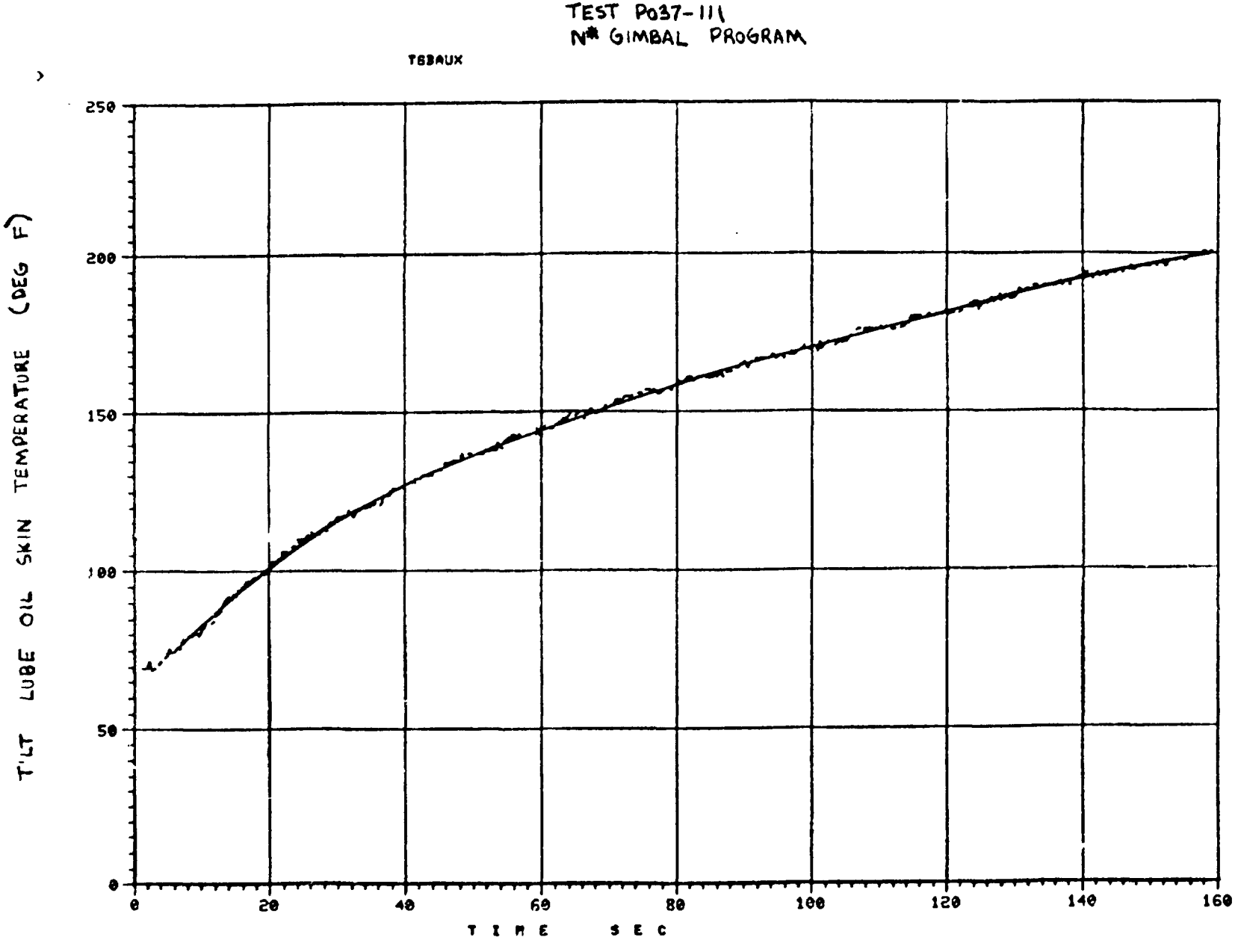

TEST P037-111
N* GIMBAL PROGRAM
T6BAUX
T'LT LUBE OIL SKIN TEMPERATURE (DEG F)
250
200
150
100
50
0
0
20
40
60
80
100
120
140
160
T I M E S E C

FIGURE C–33

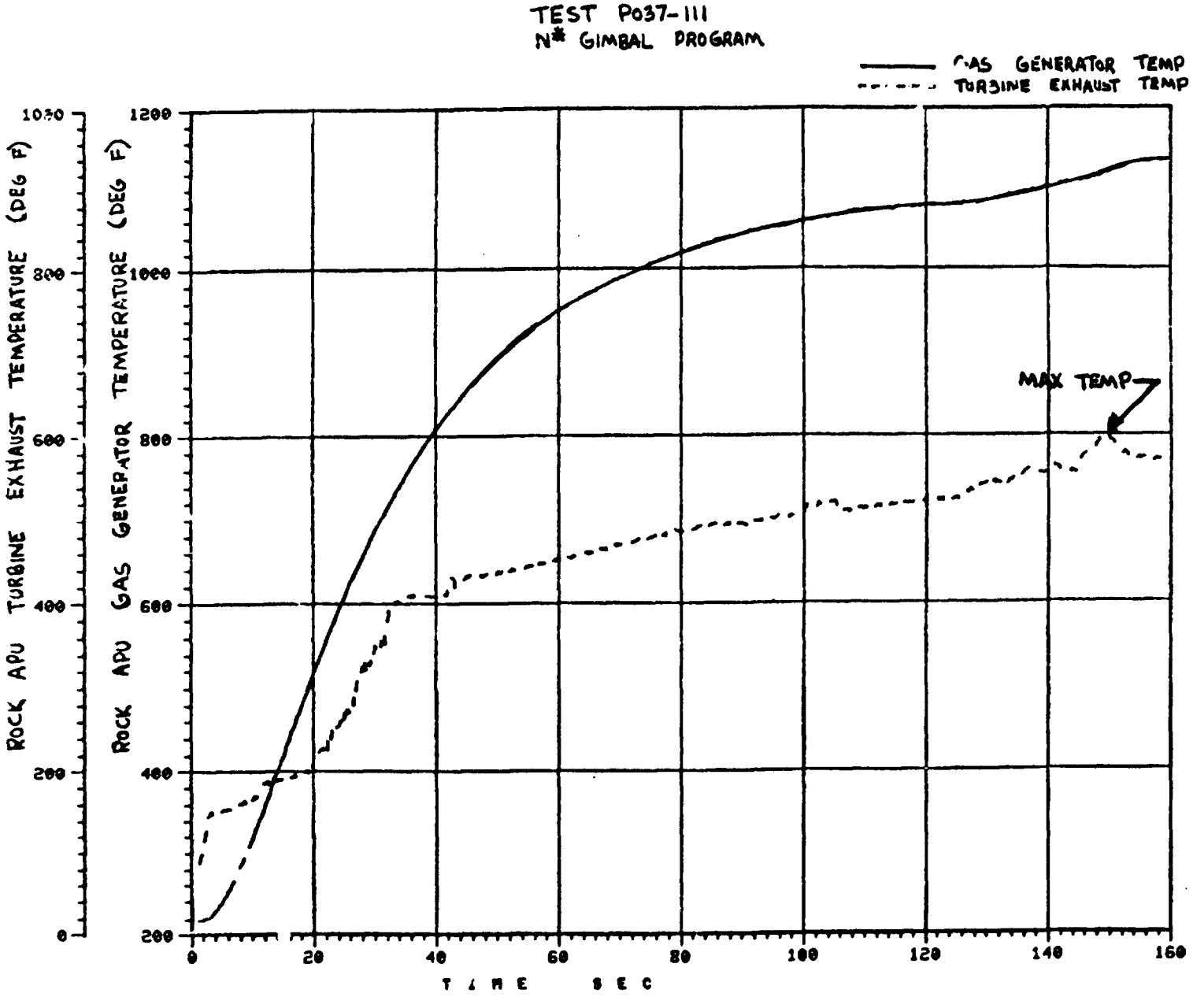

TEST P037-111
N* GIMBAL PROGRAM
GAS GENERATOR TEMP
TURBINE EXHAUST TEMP
ROCK APU TURBINE EXHAUST TEMPERATURE (DEG F)
ROCK APU GAS GENERATOR TEMPERATURE (DEG F)
MAX TEMP
TIME SEC
0
200
400
600
800
1000
1200
20
40
60
80
100
120
140
160

FIGURE C–34

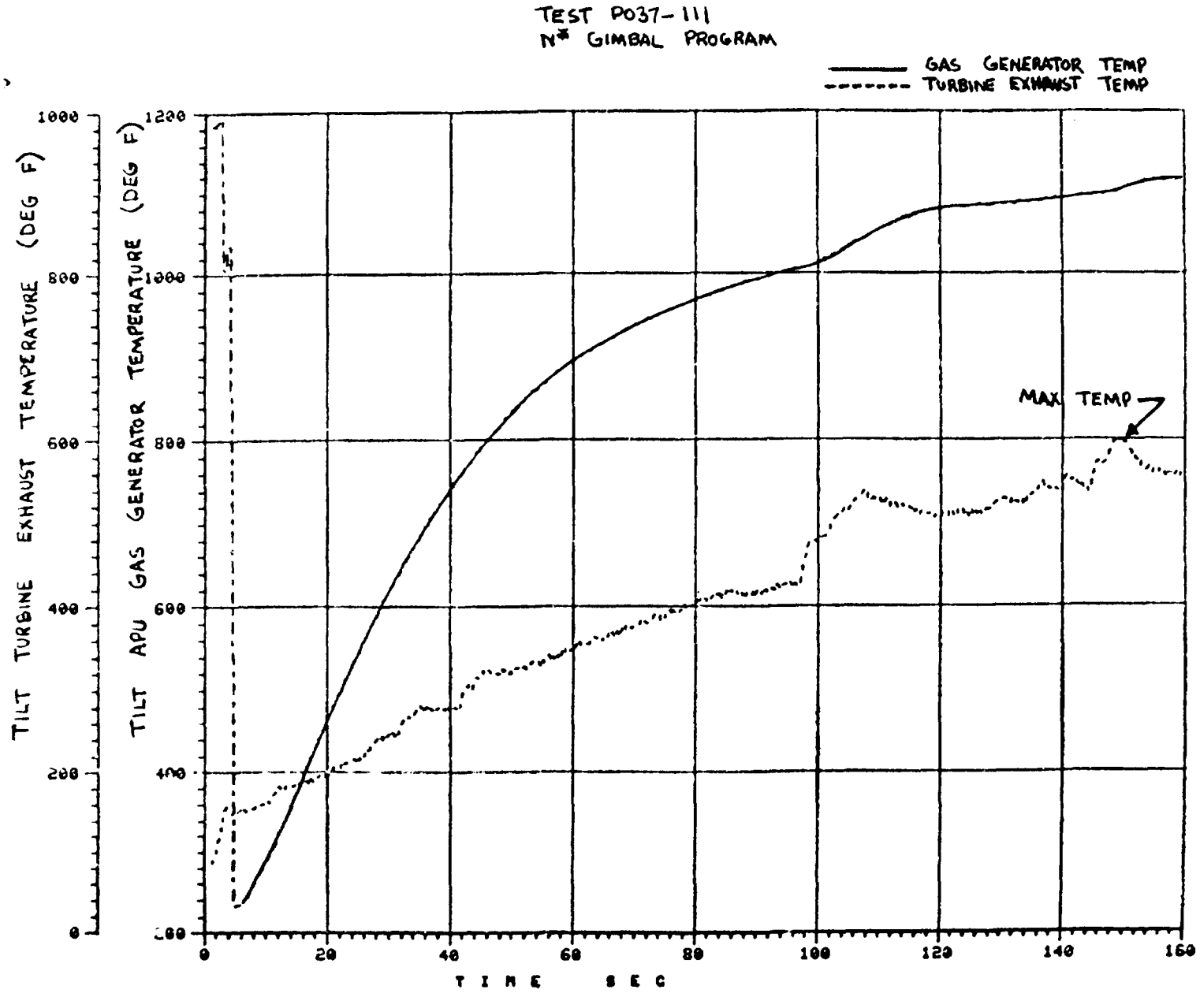

TEST P037-111
N* GIMBAL PROGRAM
GAS GENERATOR TEMP
TURBINE EXHAUST TEMP
TILT TURBINE EXHAUST TEMPERATURE (DEG F)
TILT APU GAS GENERATOR TEMPERATURE (DEG F)
MAX TEMP
TIME SEC
0
200
400
600
800
1000
1200
0
20
40
60
80
100
120
140
160

FIGURE C–35

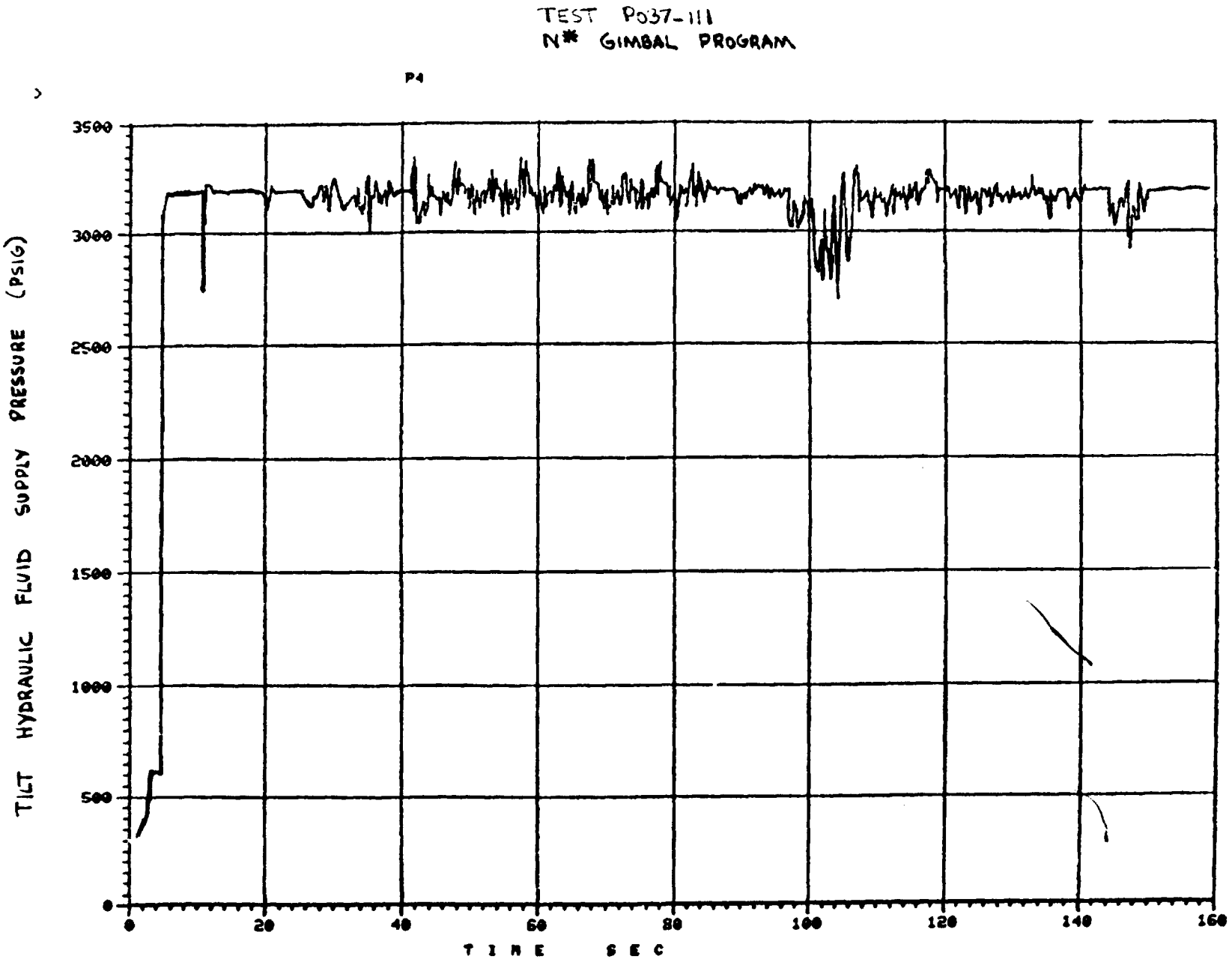

TEST P037-111
N* GIMBAL PROGRAM
P4
TILT HYDRAULIC FLUID SUPPLY PRESSURE (PSIG)
3500
3000
2500
2000
1500
1000
500
0
0
20
40
60
80
100
120
140
160
TIME SEC

FIGURE C–36

TEST P037-111
N* GIMBAL PROGRAM

APPB

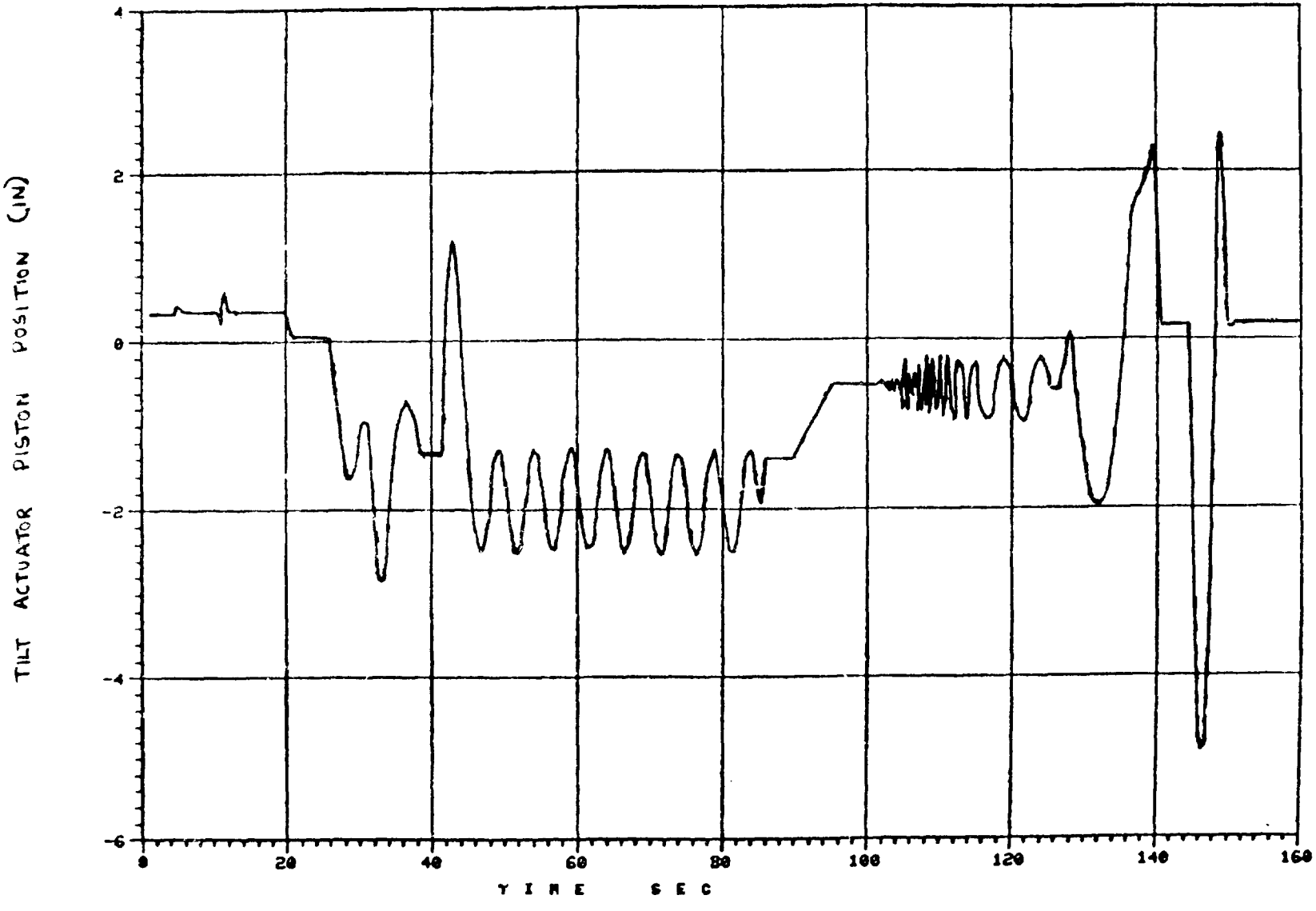


FIGURE C–37

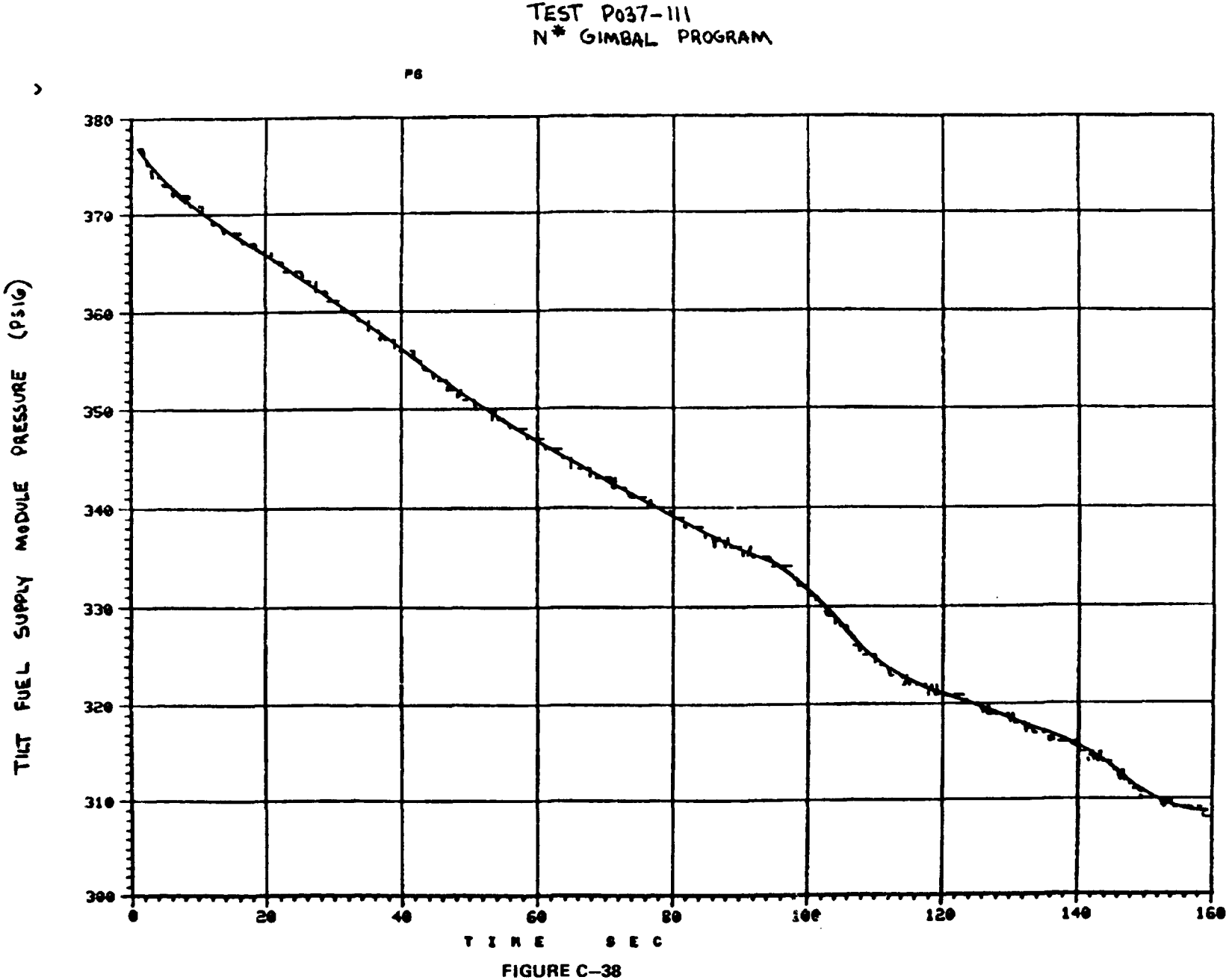

TEST P037-111
N* GIMBAL PROGRAM
P6
TILT FUEL SUPPLY MODULE PRESSURE (PSIG)
380
370
360
350
340
330
320
310
300
0
20
40
60
80
100
120
140
160
TIME SEC

FIGURE C–38

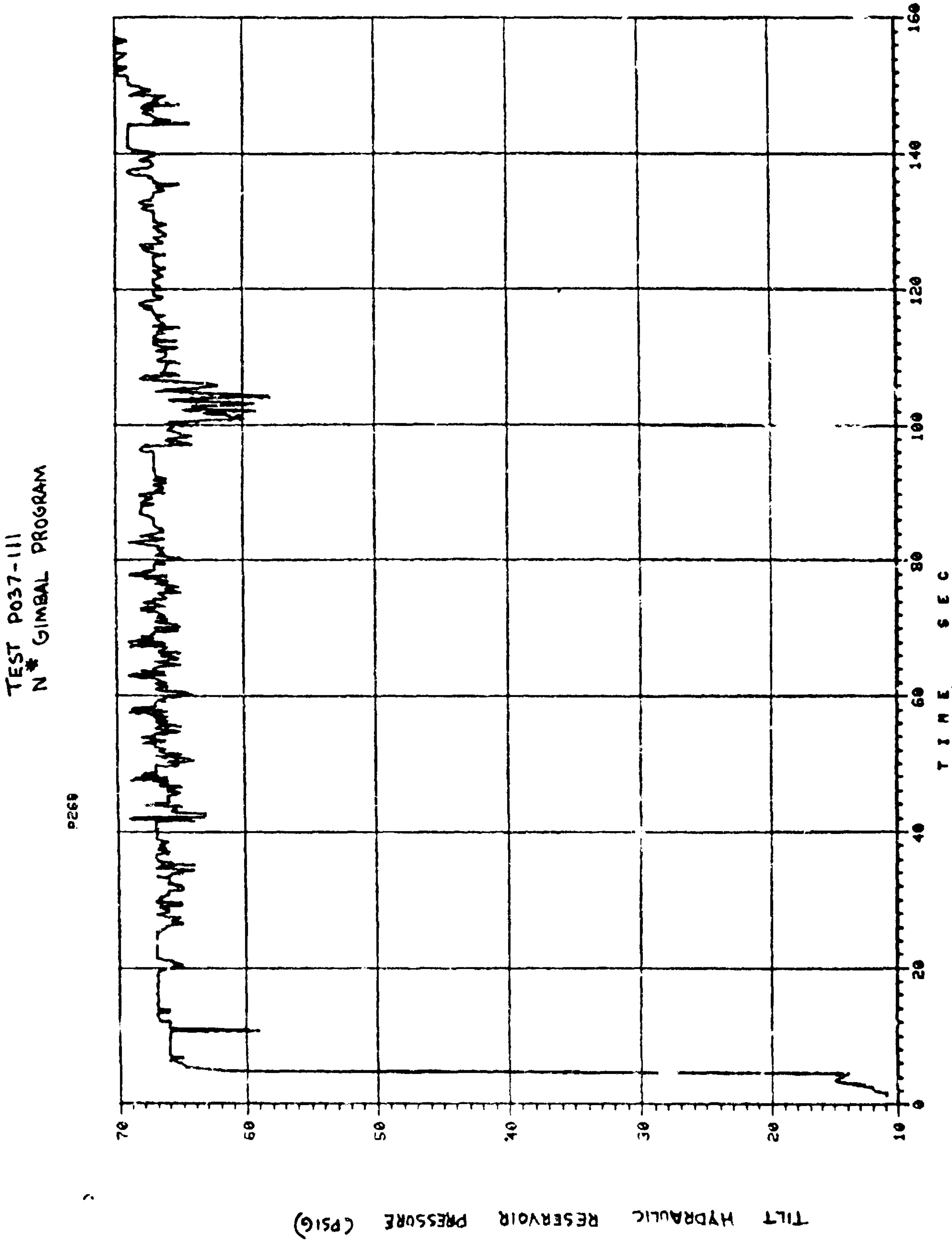


FIGURE C—39

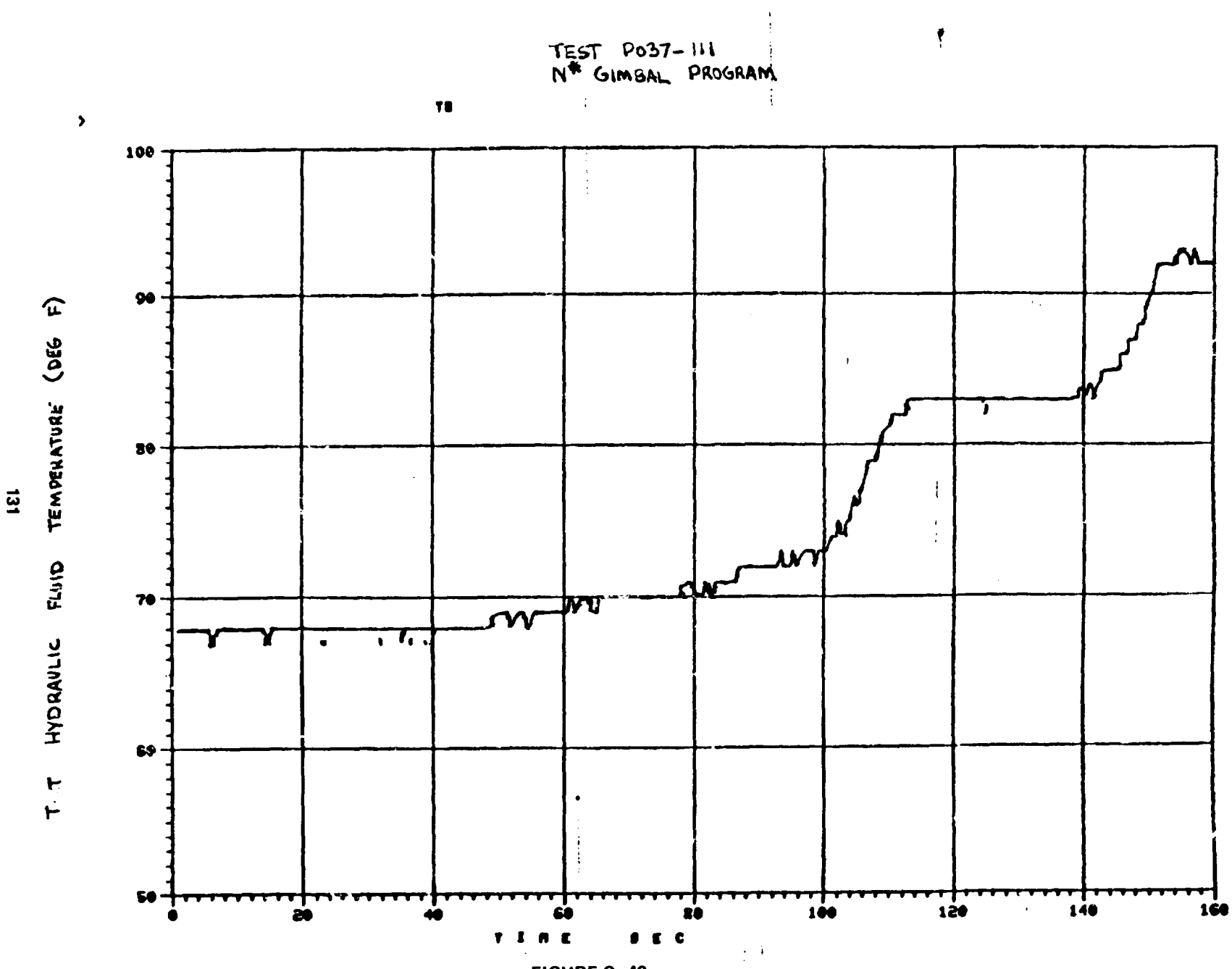

TEST P037-111
N* GIMBAL PROGRAM
T.T HYDRAULIC FLUID TEMPERATURE (DEG F)
100
90
80
70
60
50
0
20
40
60
80
100
120
140
160
TIME SEC

FIGURE C–40

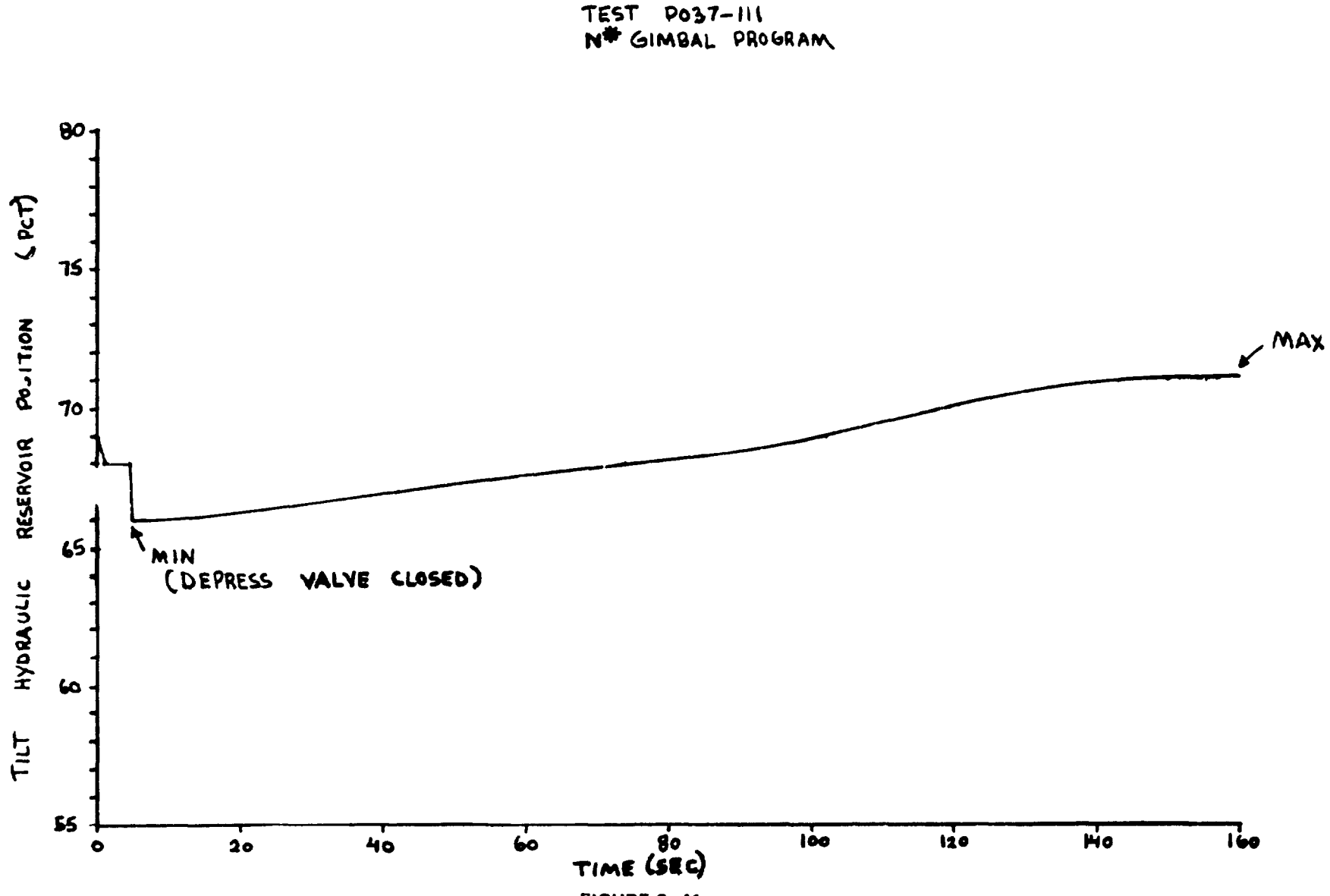

TEST P037-111
N* GIMBAL PROGRAM
TILT HYDRAULIC RESERVOIR POSITION (PCT)
80
75
70
65
60
55
MAX
MIN
(DEPRESS VALVE CLOSED)
0
20
40
60
80
100
120
140
160
TIME (SEC)

FIGURE C-41

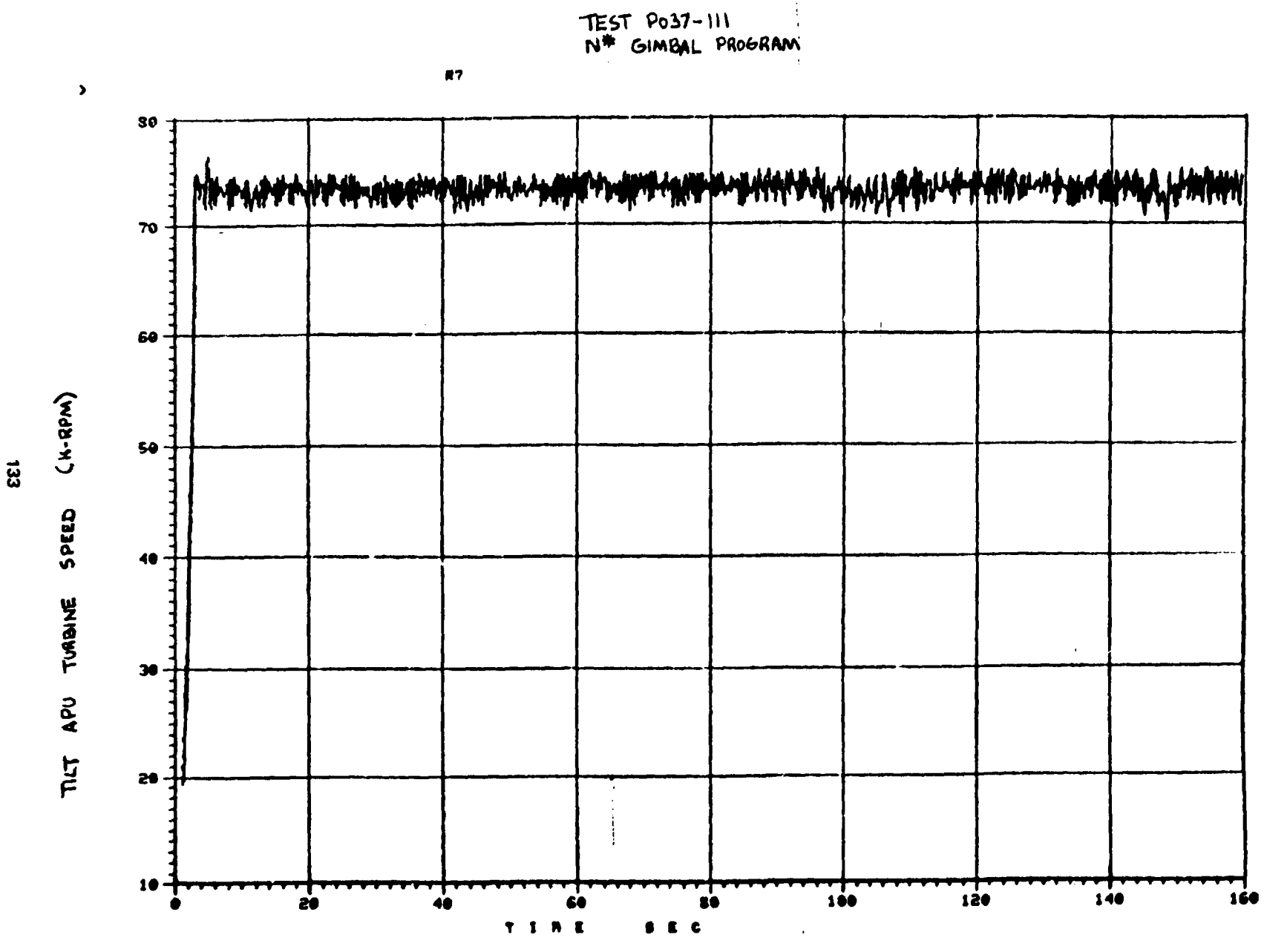

TEST P037-111
N* GIMBAL PROGRAM
R7
80
70
60
50
40
30
20
10
0
20
40
60
80
100
120
140
160
TIME SEC
TILT APU TURBINE SPEED (K-RPM)

FIGURE C–42

TEST P037-158

TEST P037-158
D GIMBAL PROGRAM

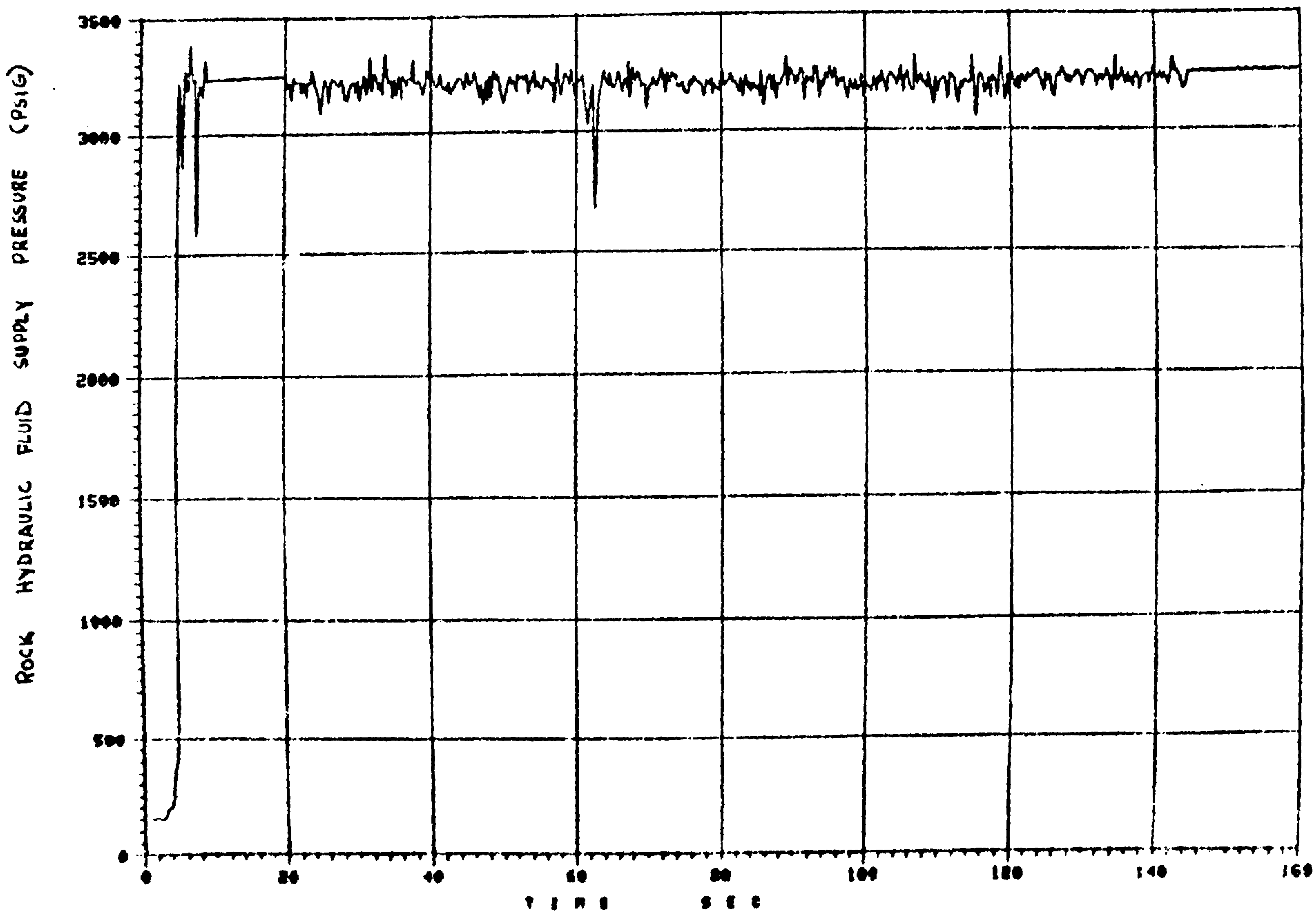


FIGURE C—43

TEST P037-158
D GIMBAL PROGRAM

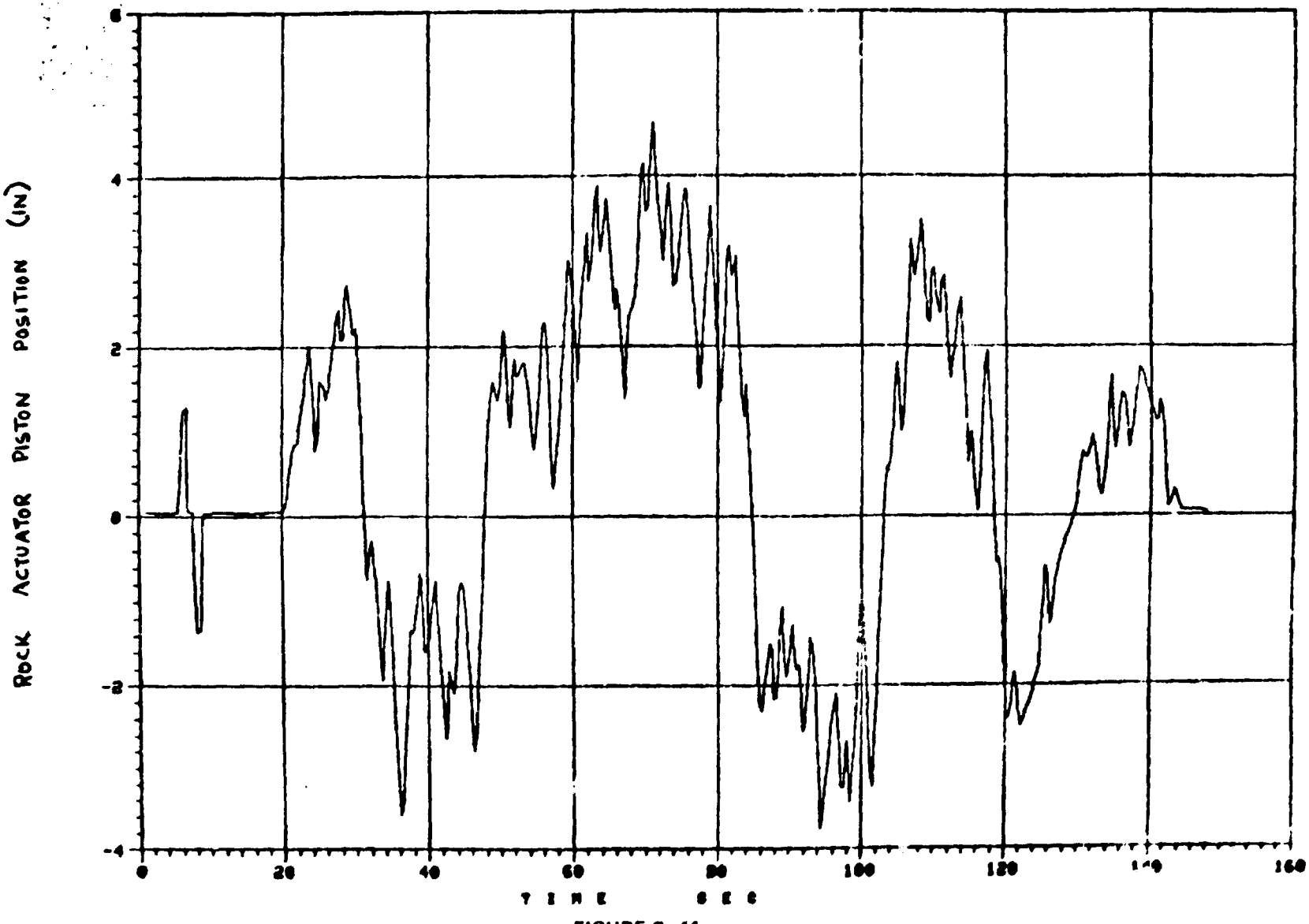


FIGURE C–44

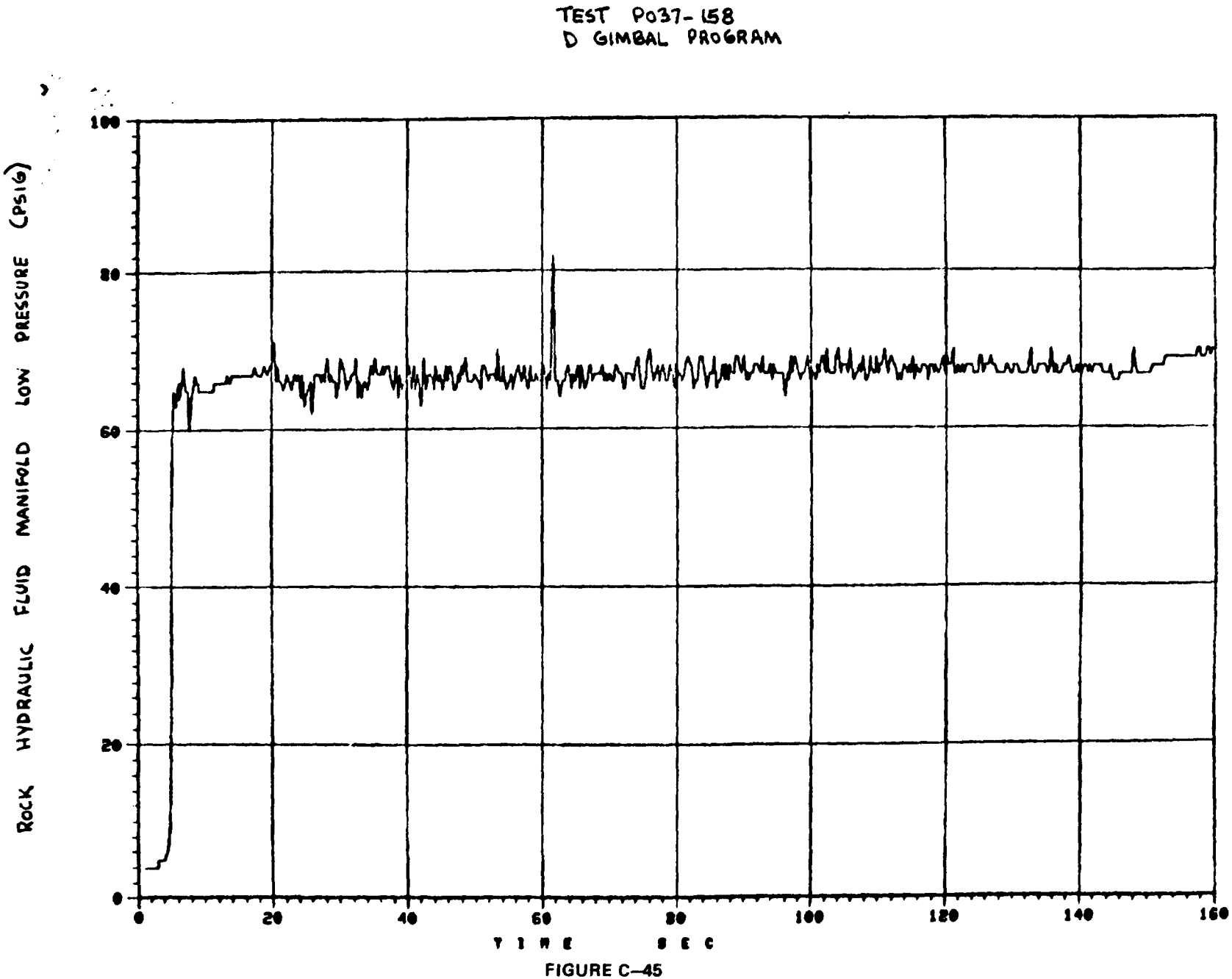

TEST P037-158
D GIMBAL PROGRAM
ROCK HYDRAULIC FLUID MANIFOLD LOW PRESSURE (PSIG)
100
80
60
40
20
0
0
20
40
60
80
100
120
140
160
TIME SEC

FIGURE C–45

TEST P037-158
D GIMBAL PROGRAM

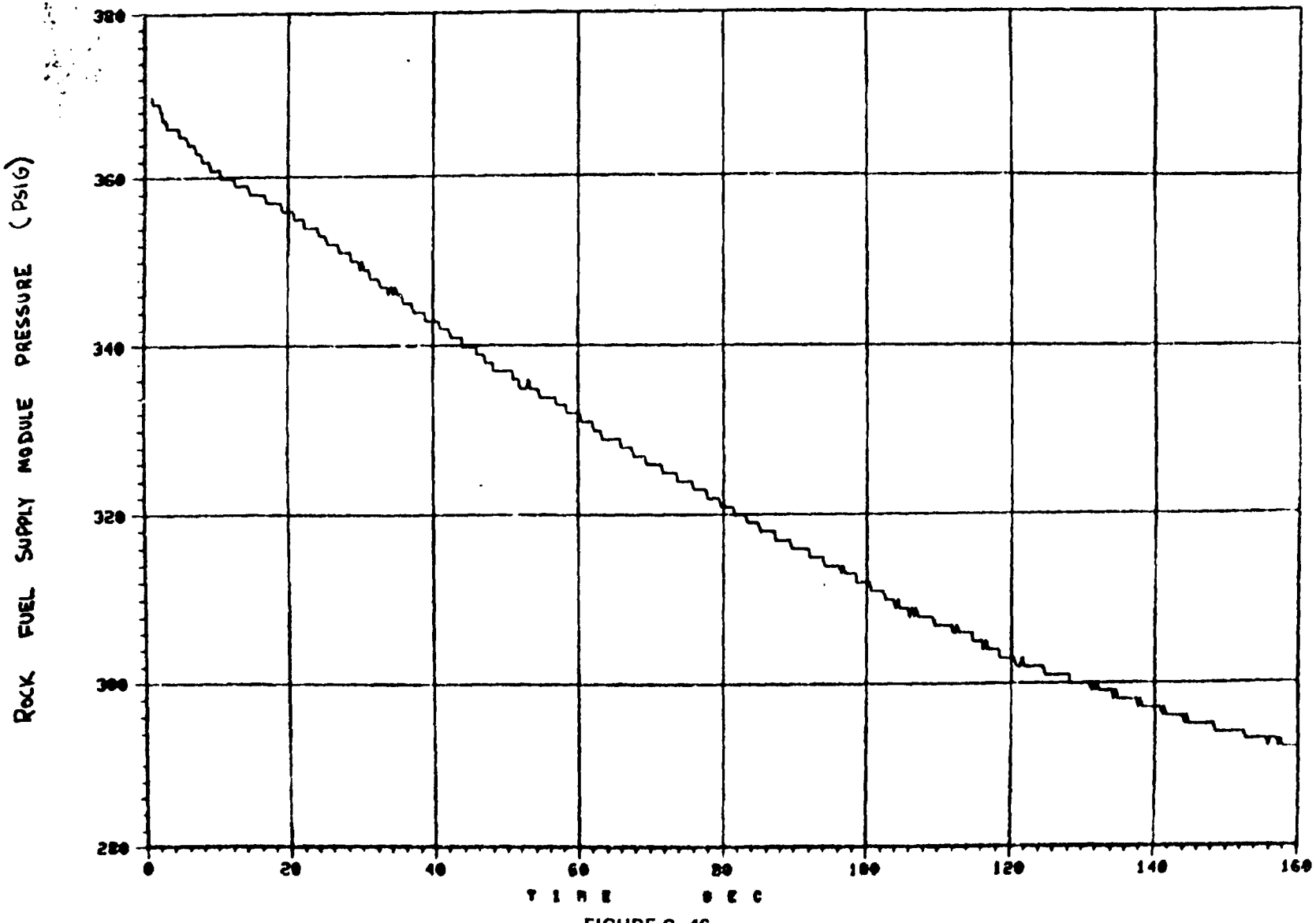


FIGURE C–46

TEST P037-15B
D GIMBAL PROGRAM

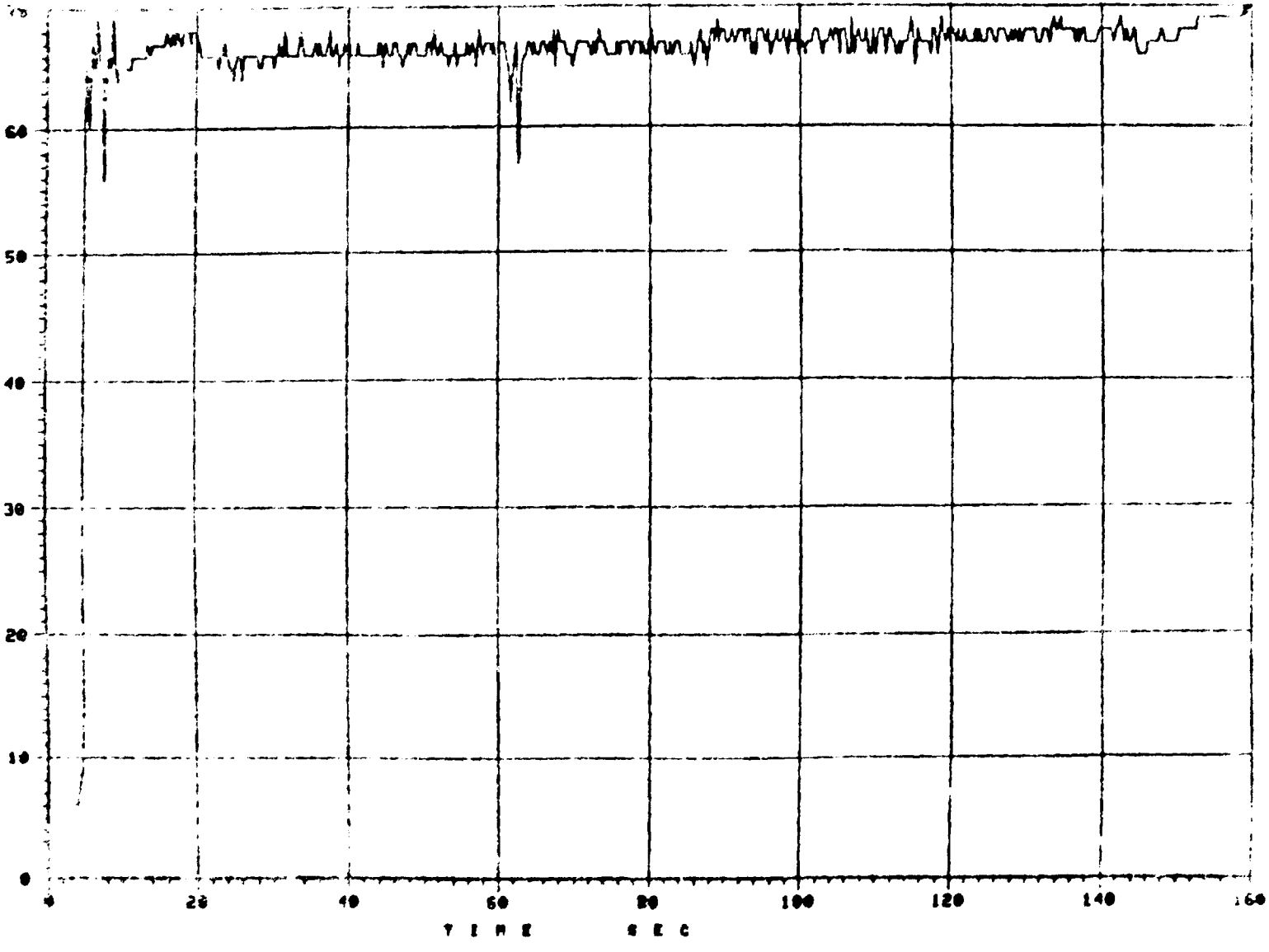
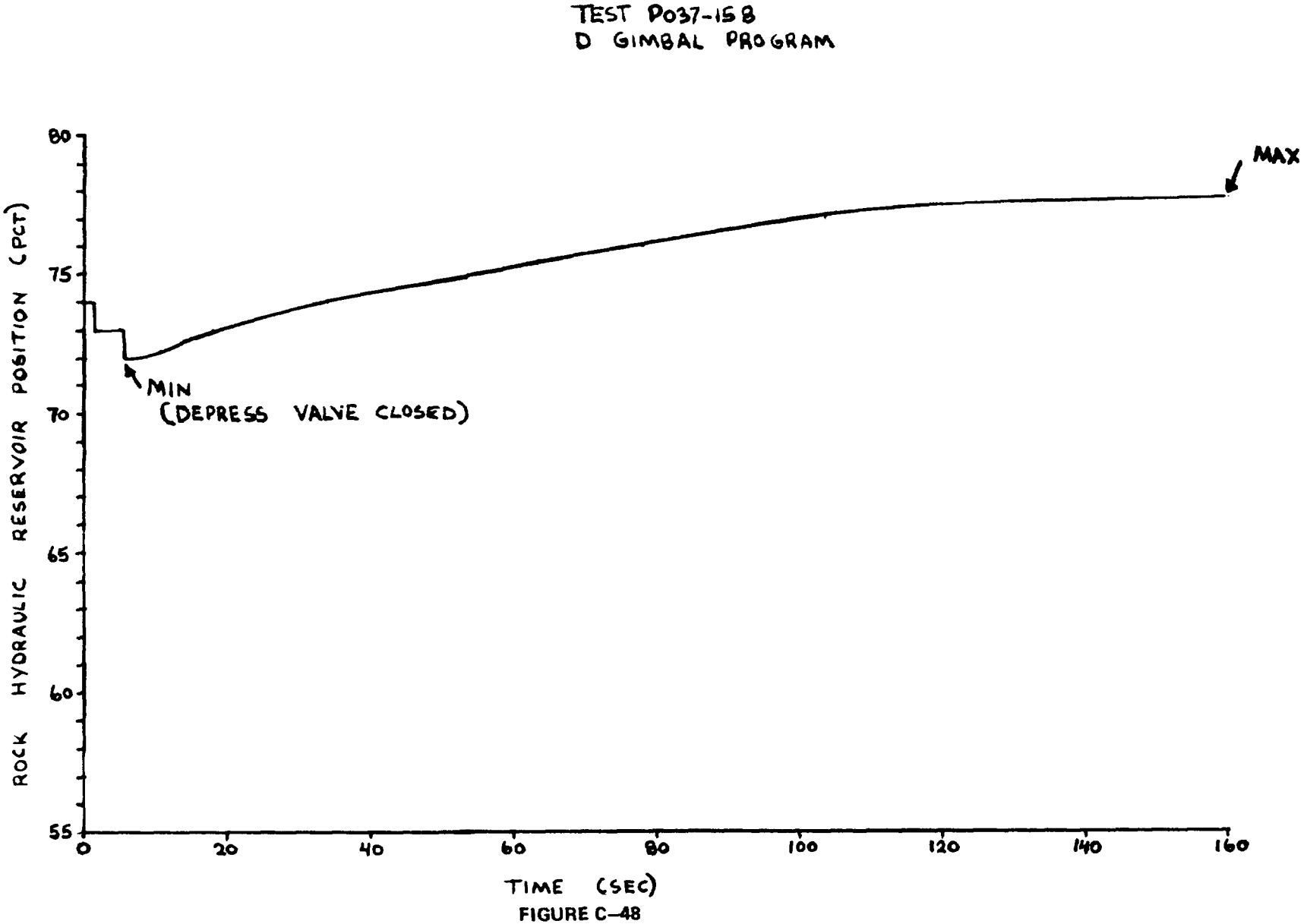


FIGURE C-47


TEST P037-15B
D GIMBAL PROGRAM
ROCK HYDRAULIC RESERVOIR POSITION (PCT)
80
75
70
65
60
55
MAX
MIN
(DEPRESS VALVE CLOSED)
0
20
40
60
80
100
120
140
160
TIME (SEC)
FIGURE C–48

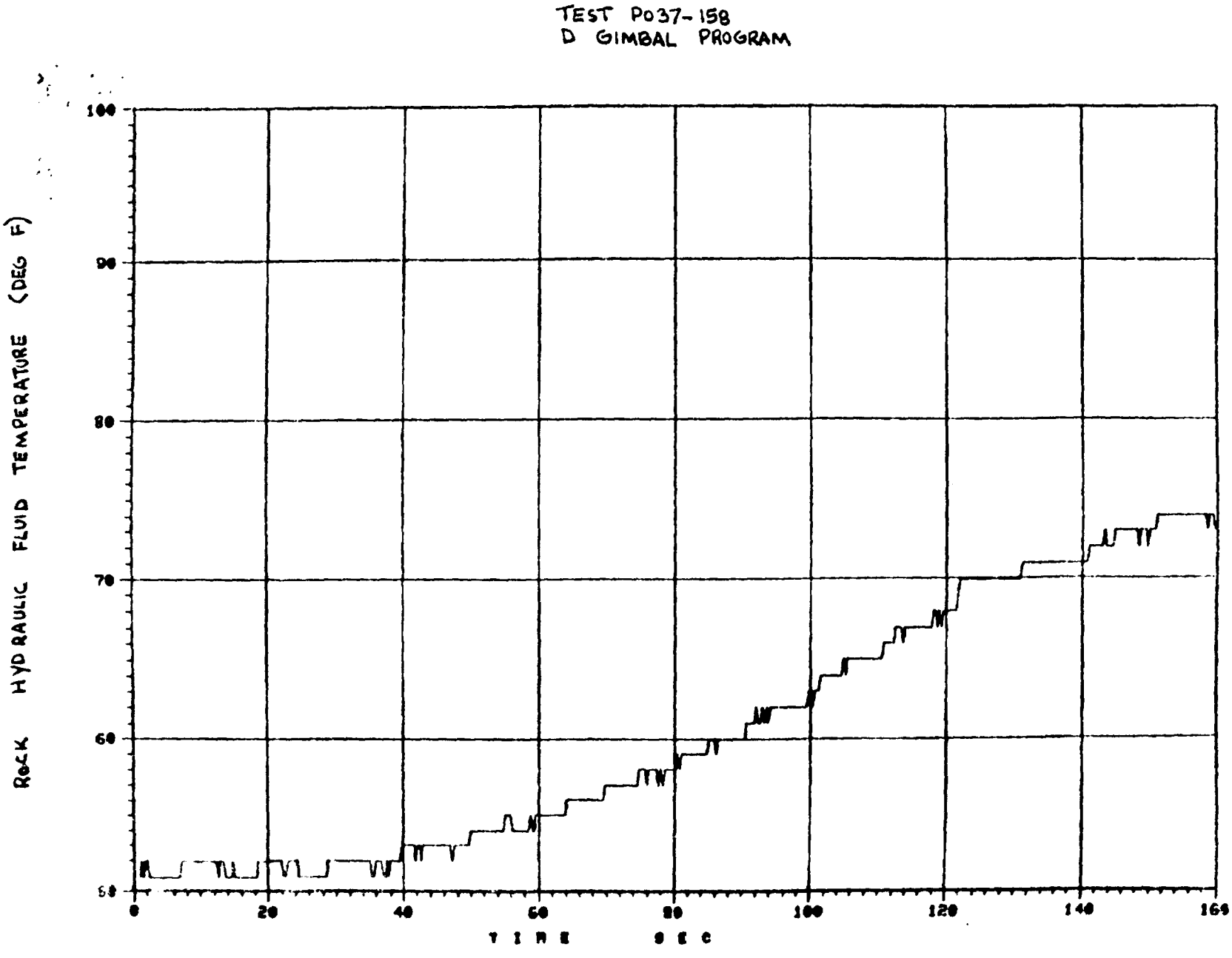

TEST P037-158
D GIMBAL PROGRAM
ROCK HYDRAULIC FLUID TEMPERATURE (DEG F)
100
90
80
70
60
50
0
20
40
60
80
100
120
140
160
TIME SEC

FIGURE C–49

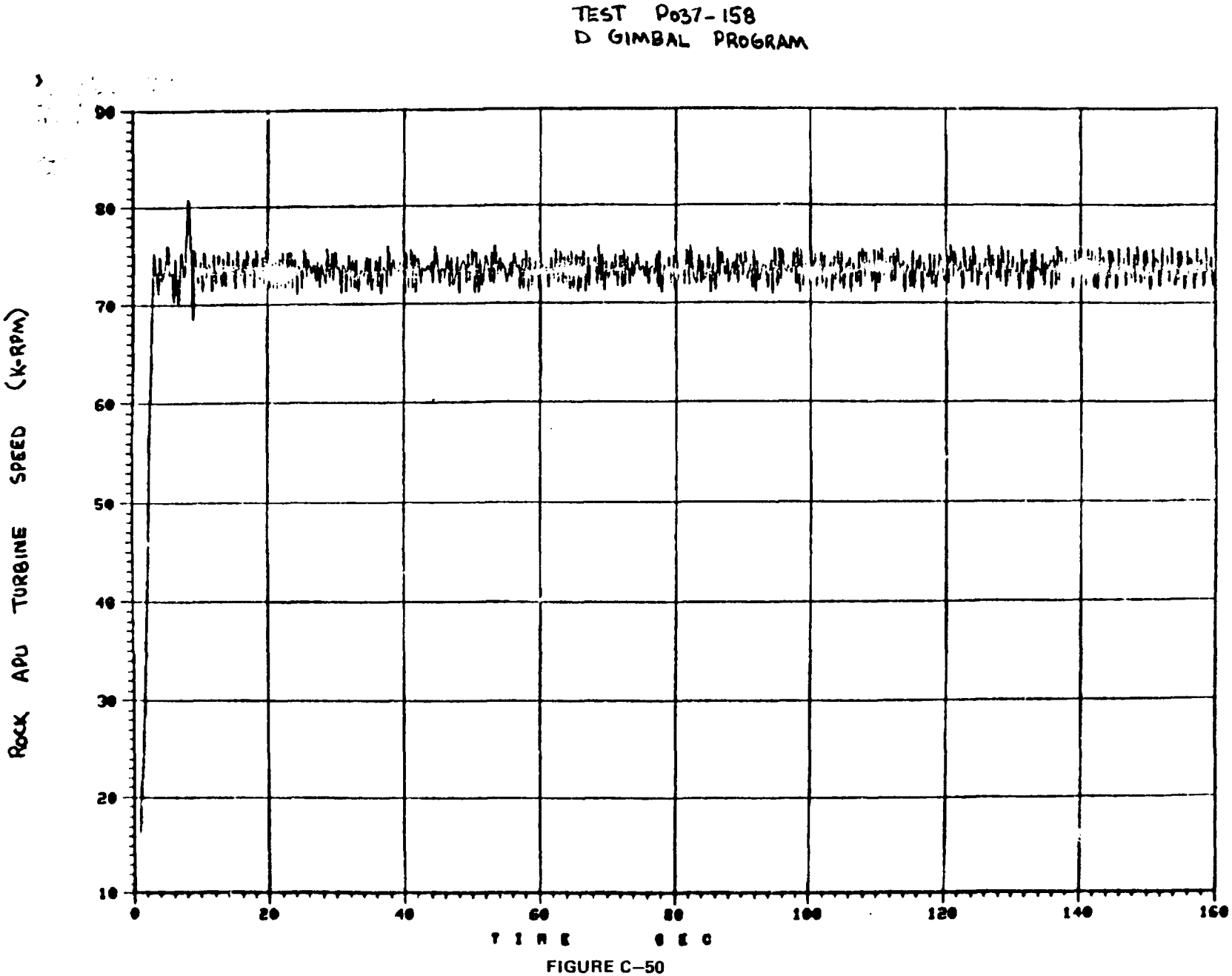

TEST P037-158
D GIMBAL PROGRAM
ROCK APU TURBINE SPEED (K-RPM)
90
80
70
60
50
40
30
20
10
0
20
40
60
80
100
120
140
160
TIME SEC

FIGURE C–50

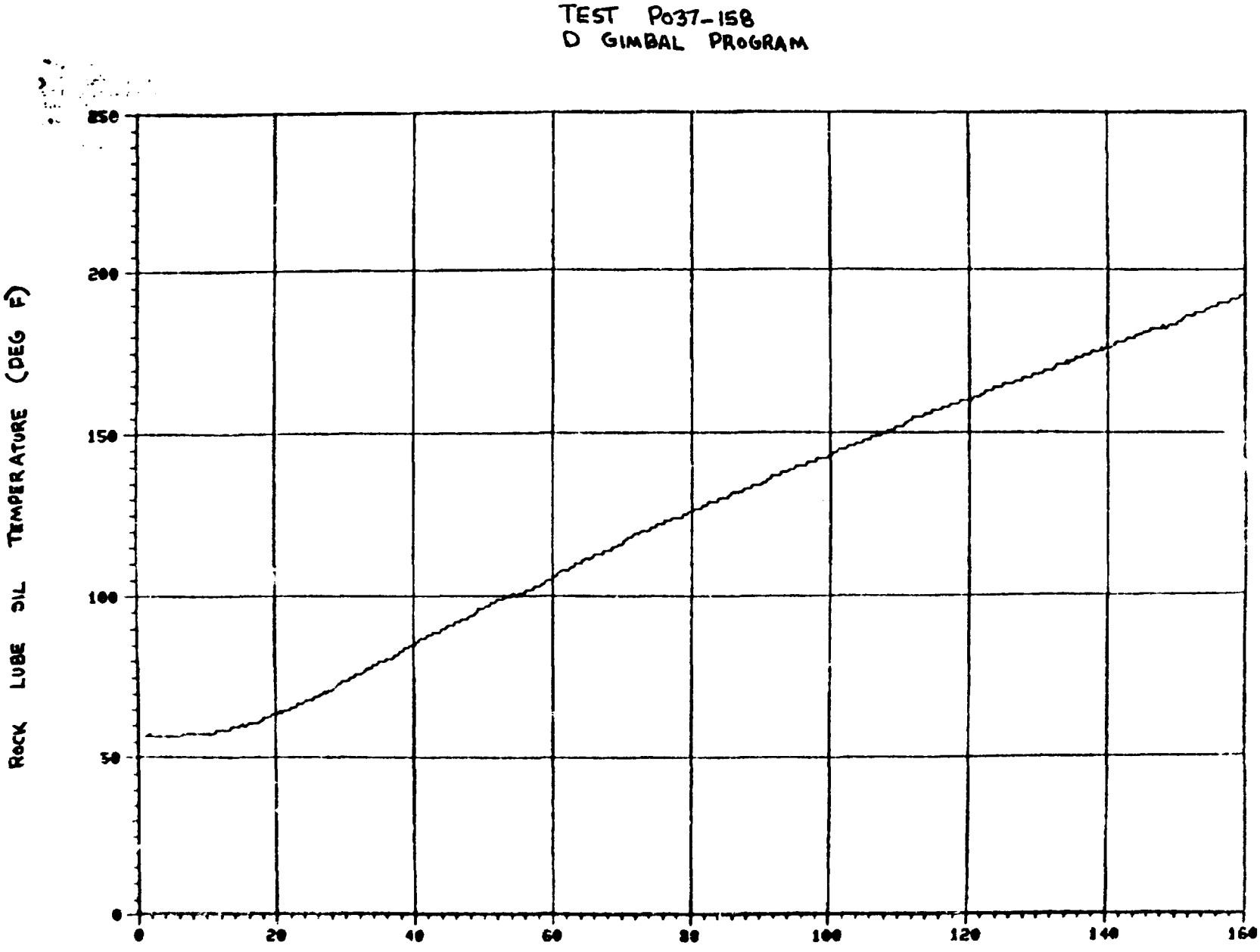

TEST P037-158
D GIMBAL PROGRAM
ROCK LUBE OIL TEMPERATURE (DEG F)
250
200
150
100
50
0
0
20
40
60
80
100
120
140
160
TIME SEC

FIGURE C-51

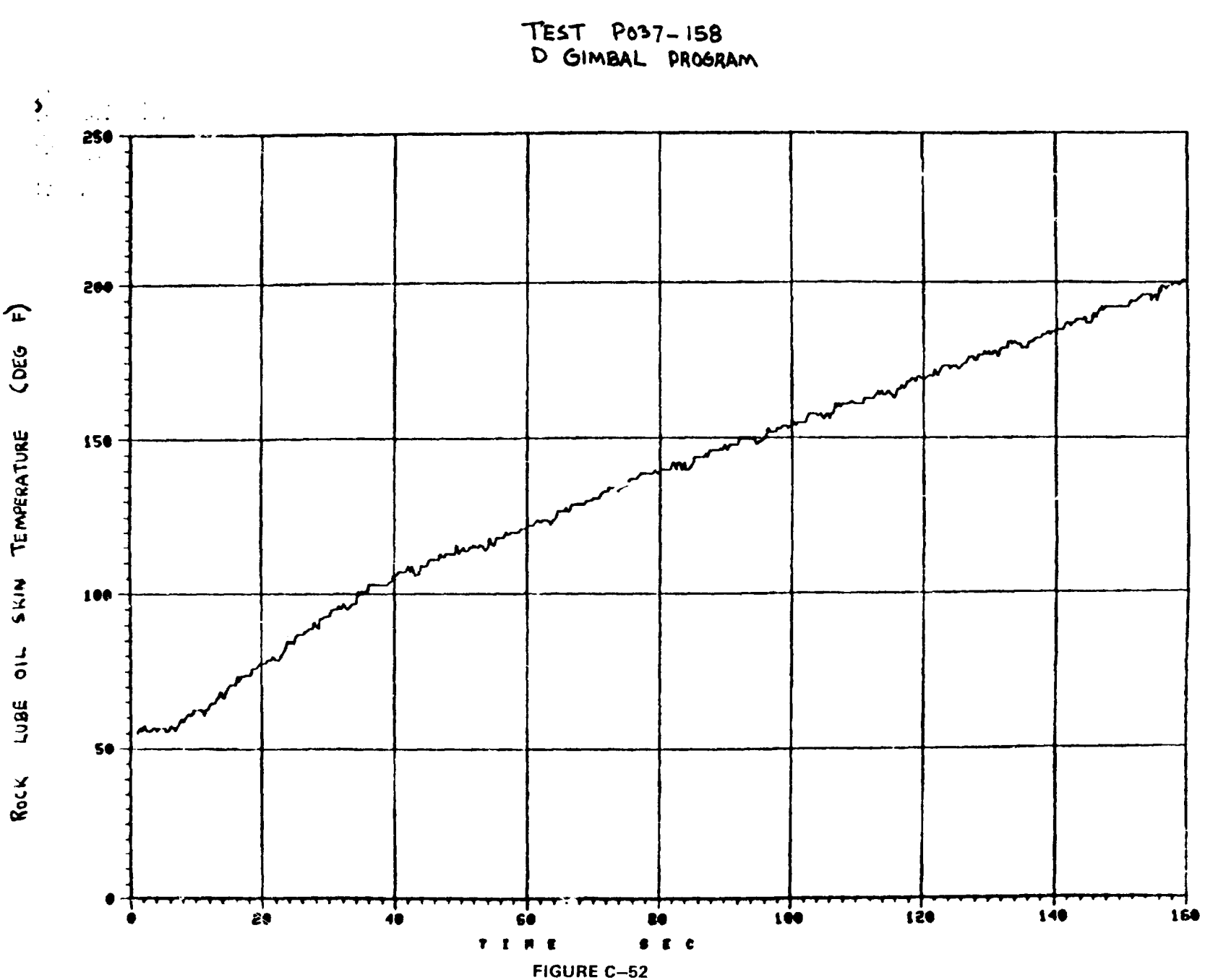

TEST P037-158
D GIMBAL PROGRAM
ROCK LUBE OIL SKIN TEMPERATURE (DEG F)
250
200
150
100
50
0
0
20
40
60
80
100
120
140
160
TIME SEC

FIGURE C–52

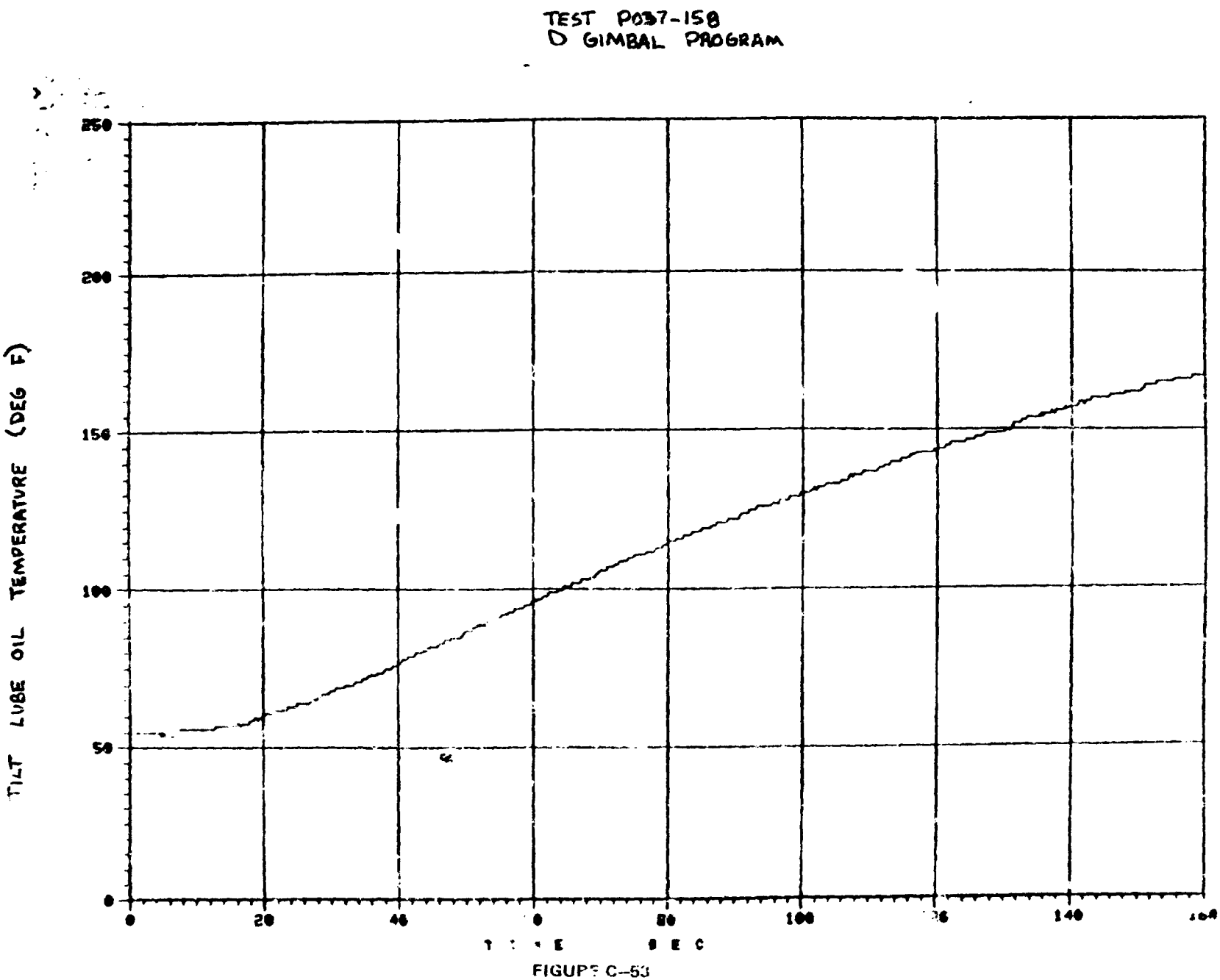

TEST P037-158
D GIMBAL PROGRAM
TILT LUBE OIL TEMPERATURE (DEG F)
250
200
150
100
50
0
0
20
40
0
80
100
120
140
TIME SEC

FIGURE C-53

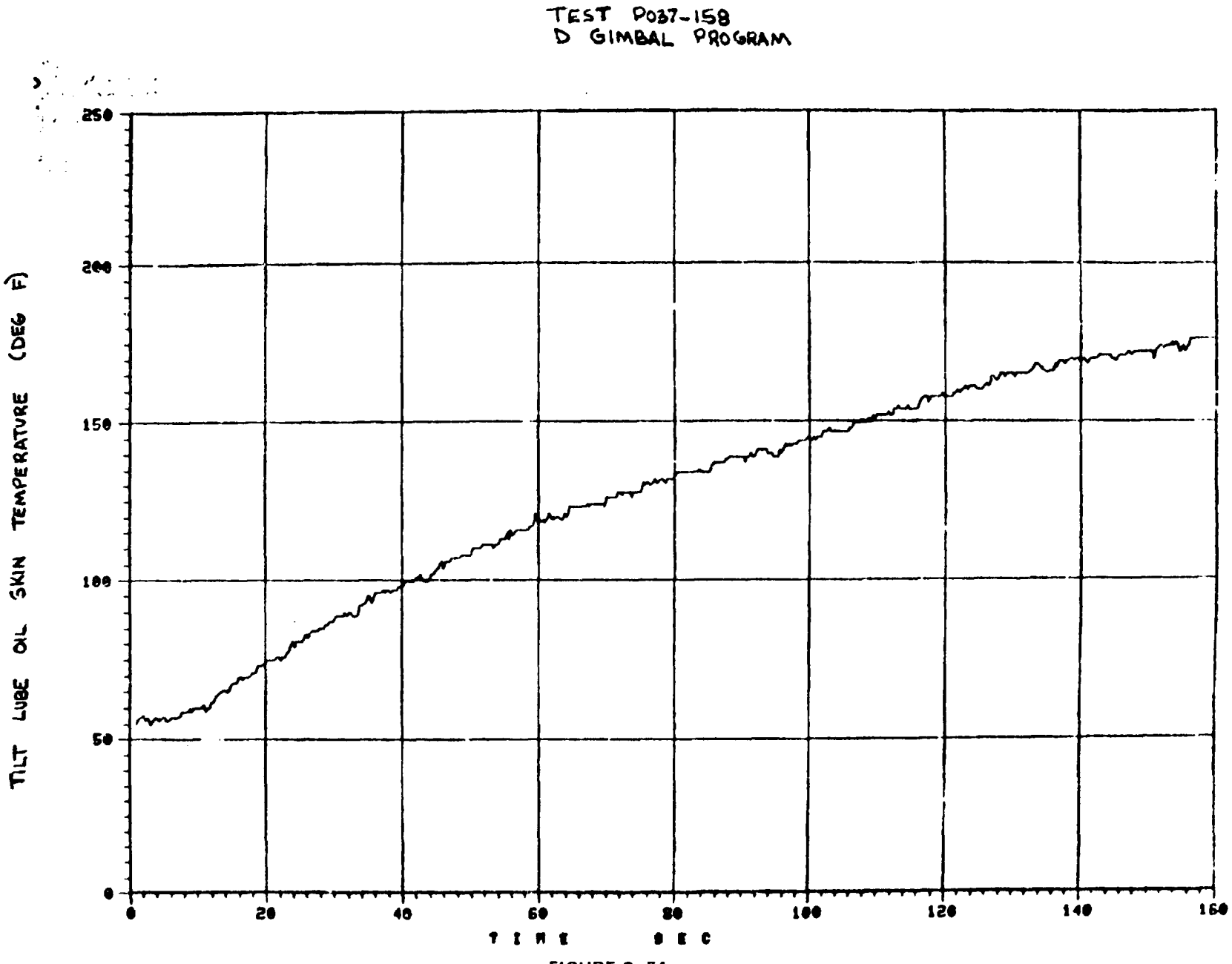

TEST P037-158
D GIMBAL PROGRAM
TILT LUBE OIL SKIN TEMPERATURE (DEG F)
250
200
150
100
50
0
0
20
40
60
80
100
120
140
160
TIME SEC

FIGURE C–54

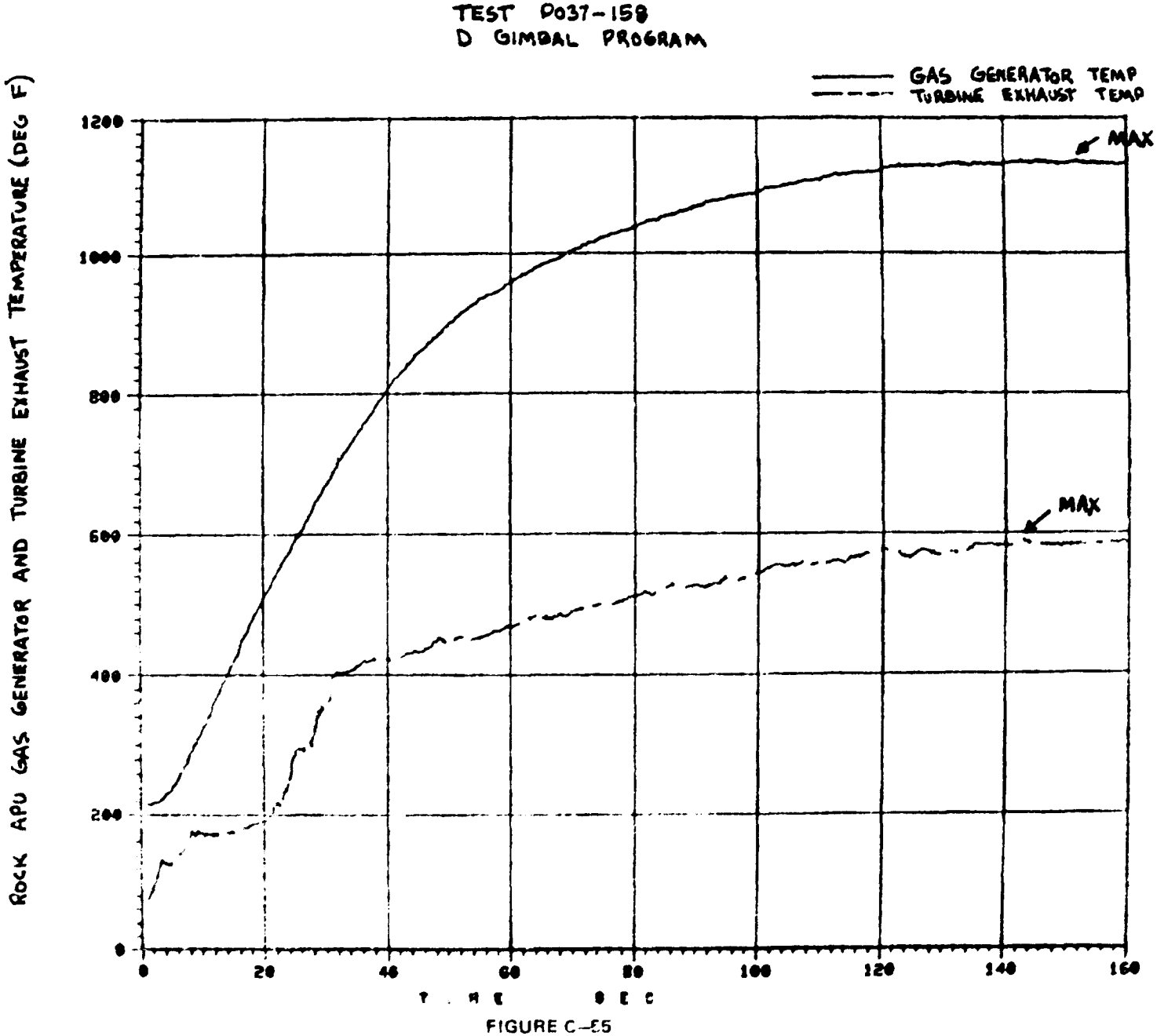

TEST P037-158
D GIMBAL PROGRAM
GAS GENERATOR TEMP
TURBINE EXHAUST TEMP
ROCK APU GAS GENERATOR AND TURBINE EXHAUST TEMPERATURE (DEG F)
1200
1000
800
600
400
200
0
MAX
MAX
0
20
40
60
80
100
120
140
160
TIME SEC

FIGURE C-55

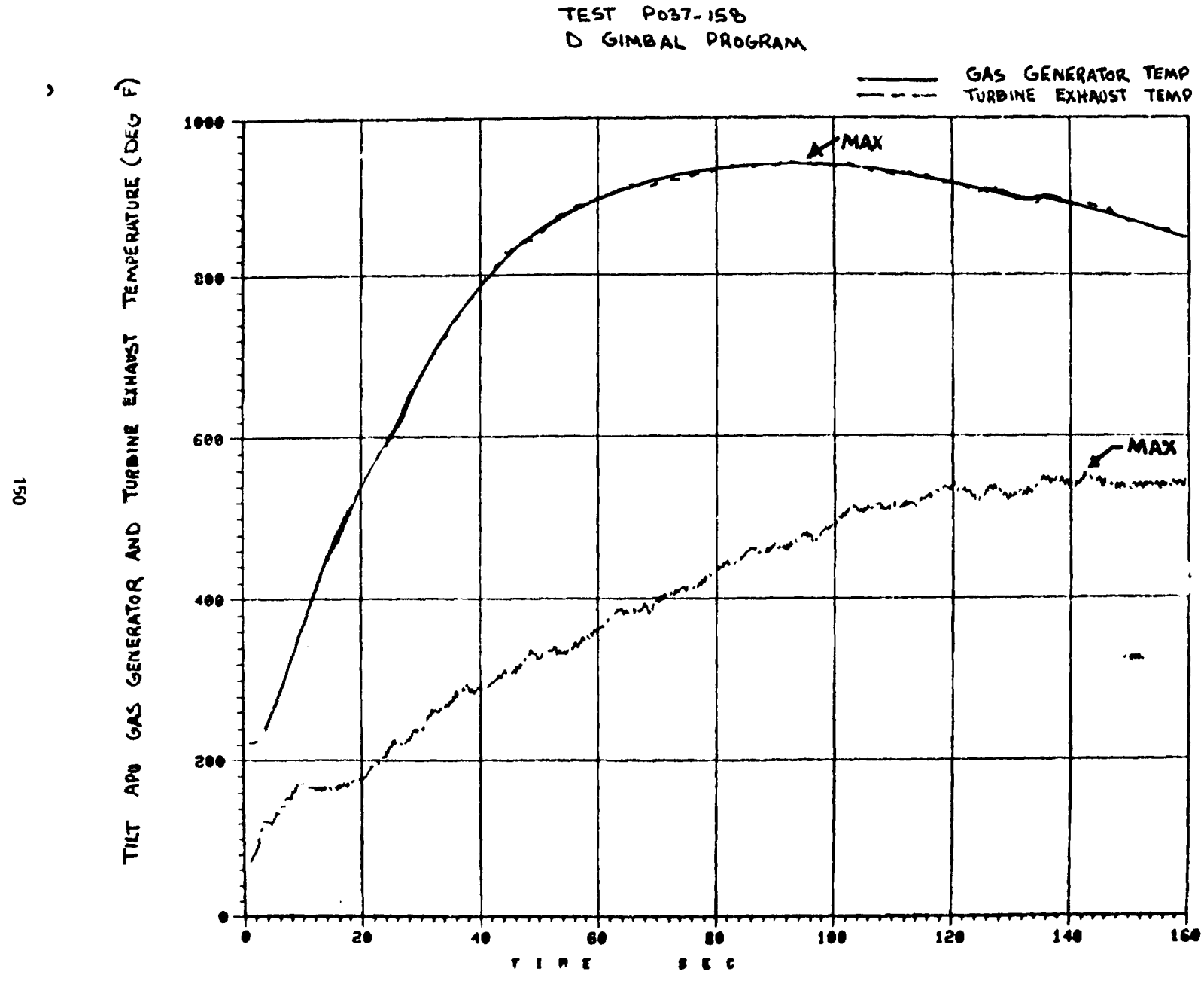

TEST P037-158
D GIMBAL PROGRAM
GAS GENERATOR TEMP
TURBINE EXHAUST TEMP
TILT APU GAS GENERATOR AND TURBINE EXHAUST TEMPERATURE (DEG F)
1000
800
600
400
200
0
MAX
MAX
0
20
40
60
80
100
120
140
160
TIME SEC

FIGURE C–56

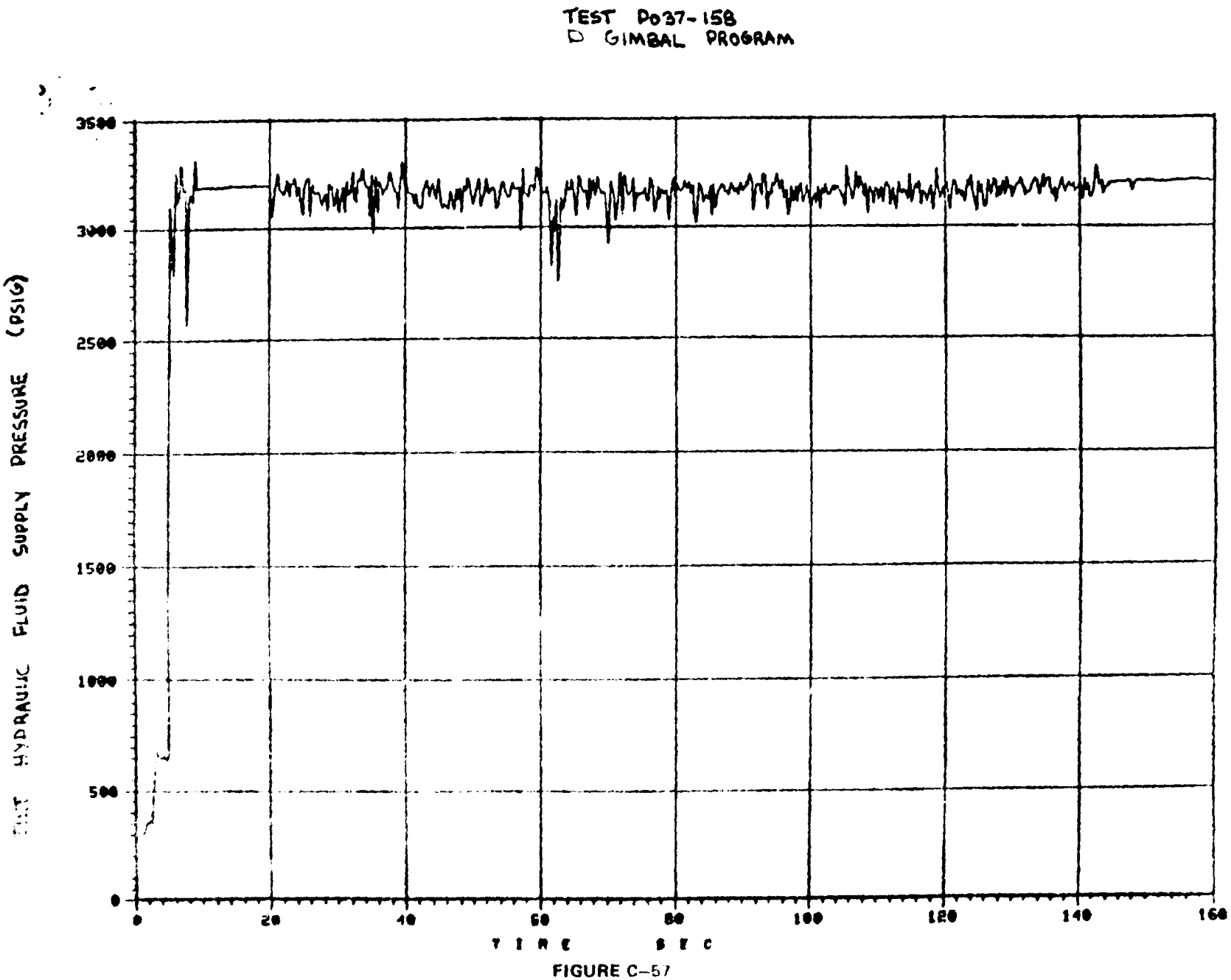

TEST P037-158
D GIMBAL PROGRAM
3500
3000
2500
2000
1500
1000
500
0
0
20
40
60
80
100
120
140
160
TIME SEC
HYDRAULIC FLUID SUPPLY PRESSURE (PSIG)

FIGURE C–57

TEST P037-158
D GIMBAL PROGRAM

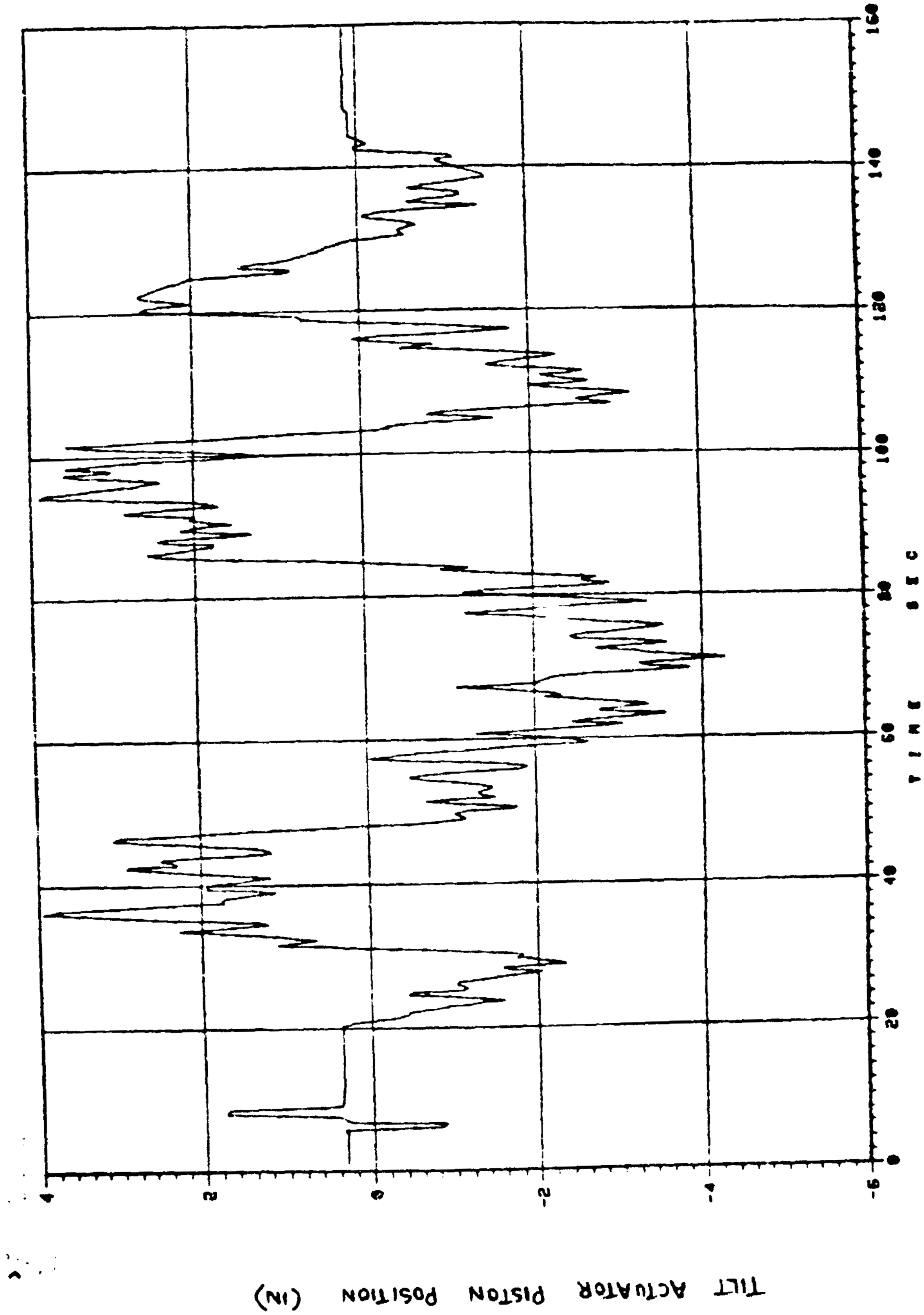


FIGURE C-58

TEST P037-158
D GIMBAL PROGRAM

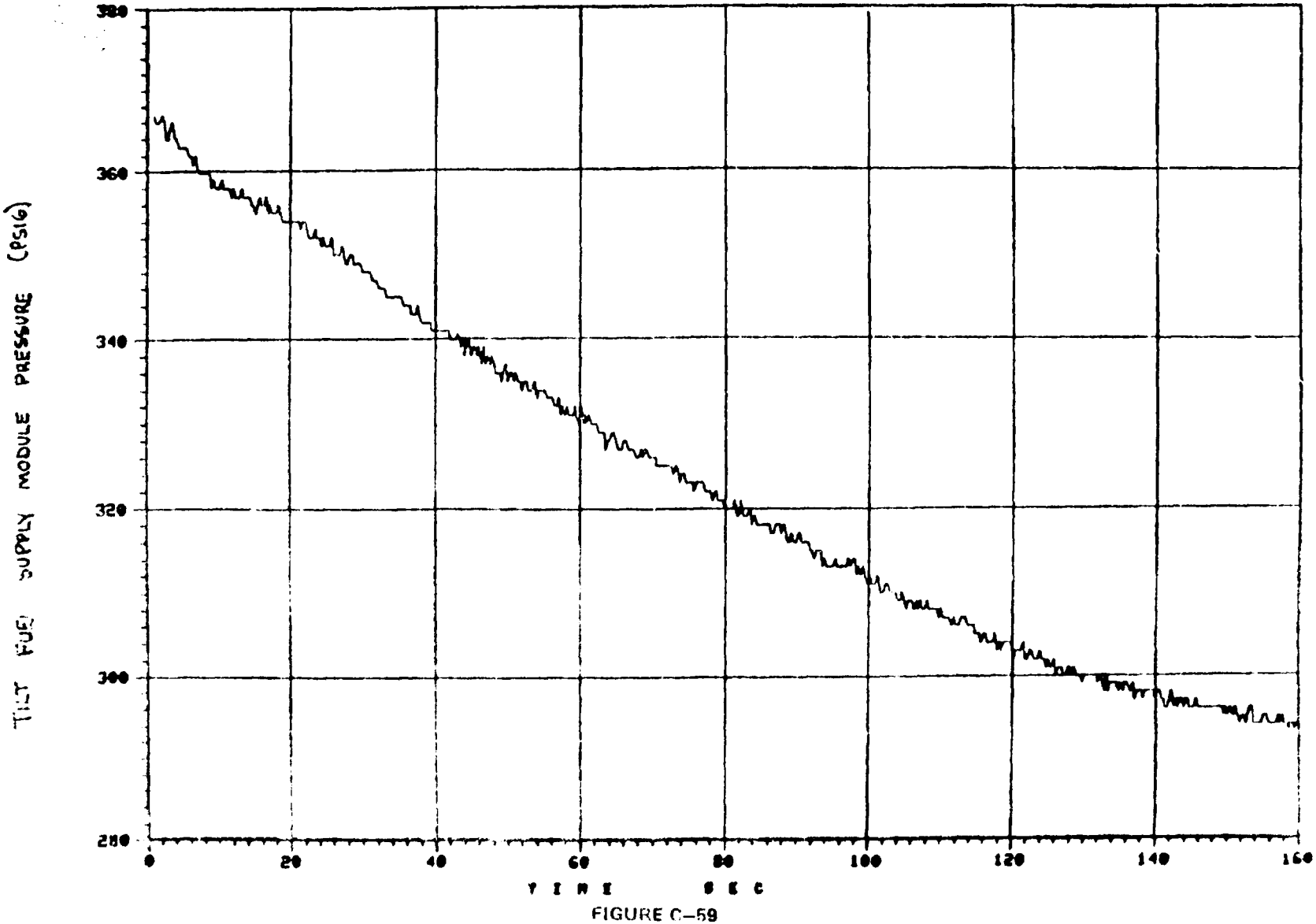


FIGURE C-59

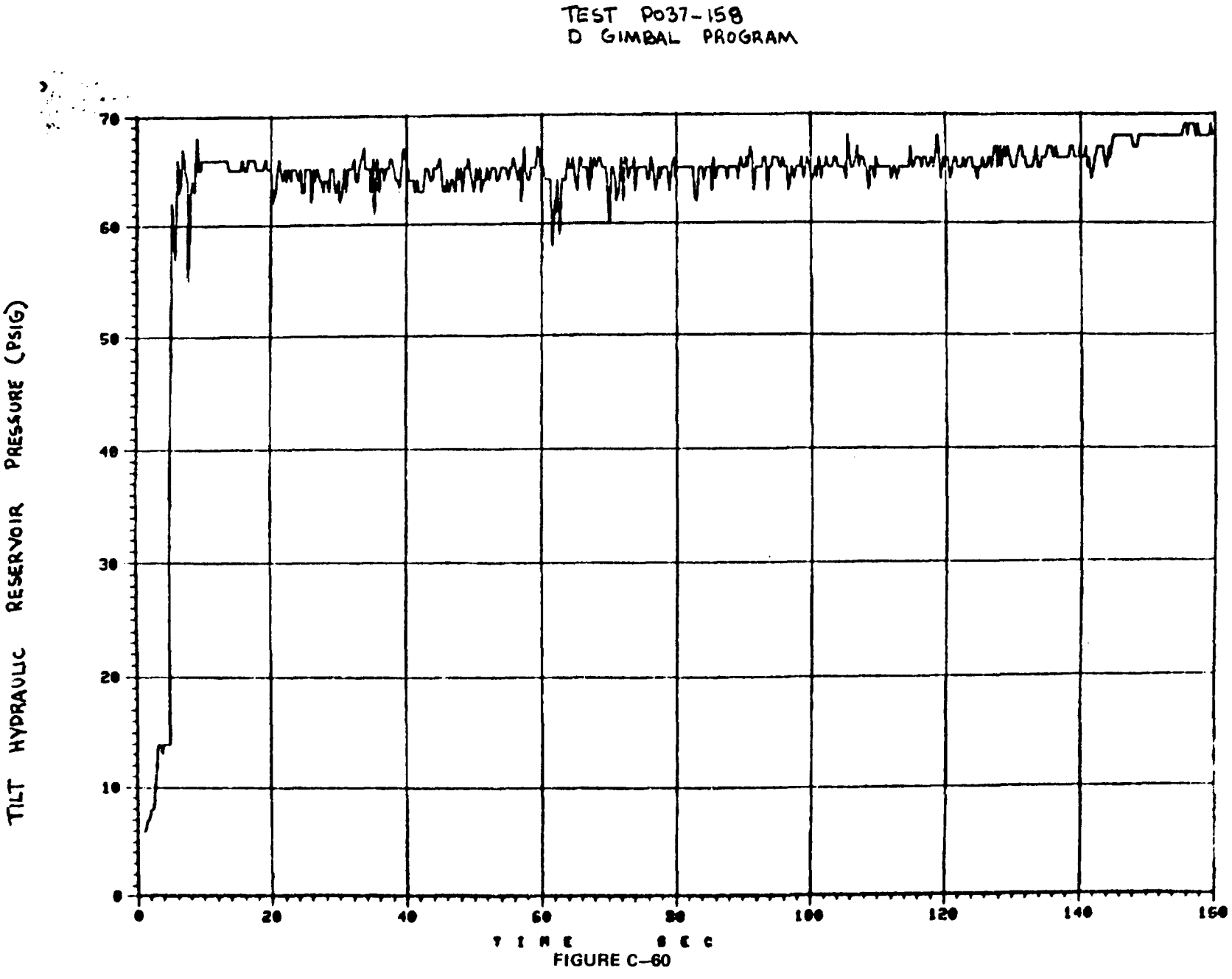

TEST P037-158
D GIMBAL PROGRAM
TILT HYDRAULIC RESERVOIR PRESSURE (PSIG)
0
10
20
30
40
50
60
70
0
20
40
60
80
100
120
140
160
TIME SEC

FIGURE C–60

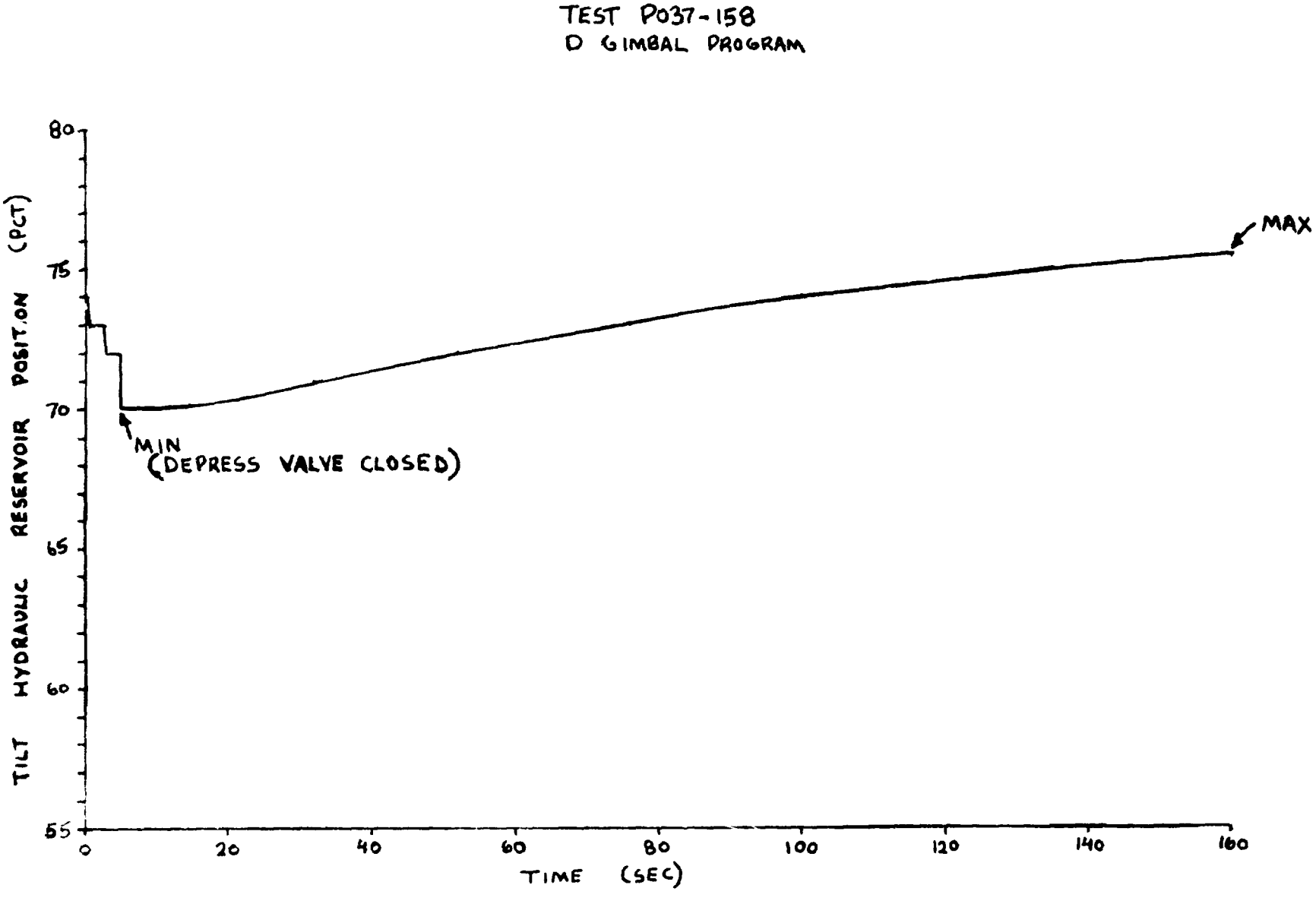

TEST P037-158
D GIMBAL PROGRAM
TILT HYDRAULIC RESERVOIR POSITION (PCT)
80
75
70
65
60
55
MAX
MIN
(DEPRESS VALVE CLOSED)
0
20
40
60
80
100
120
140
160
TIME (SEC)

FIGURE C–61

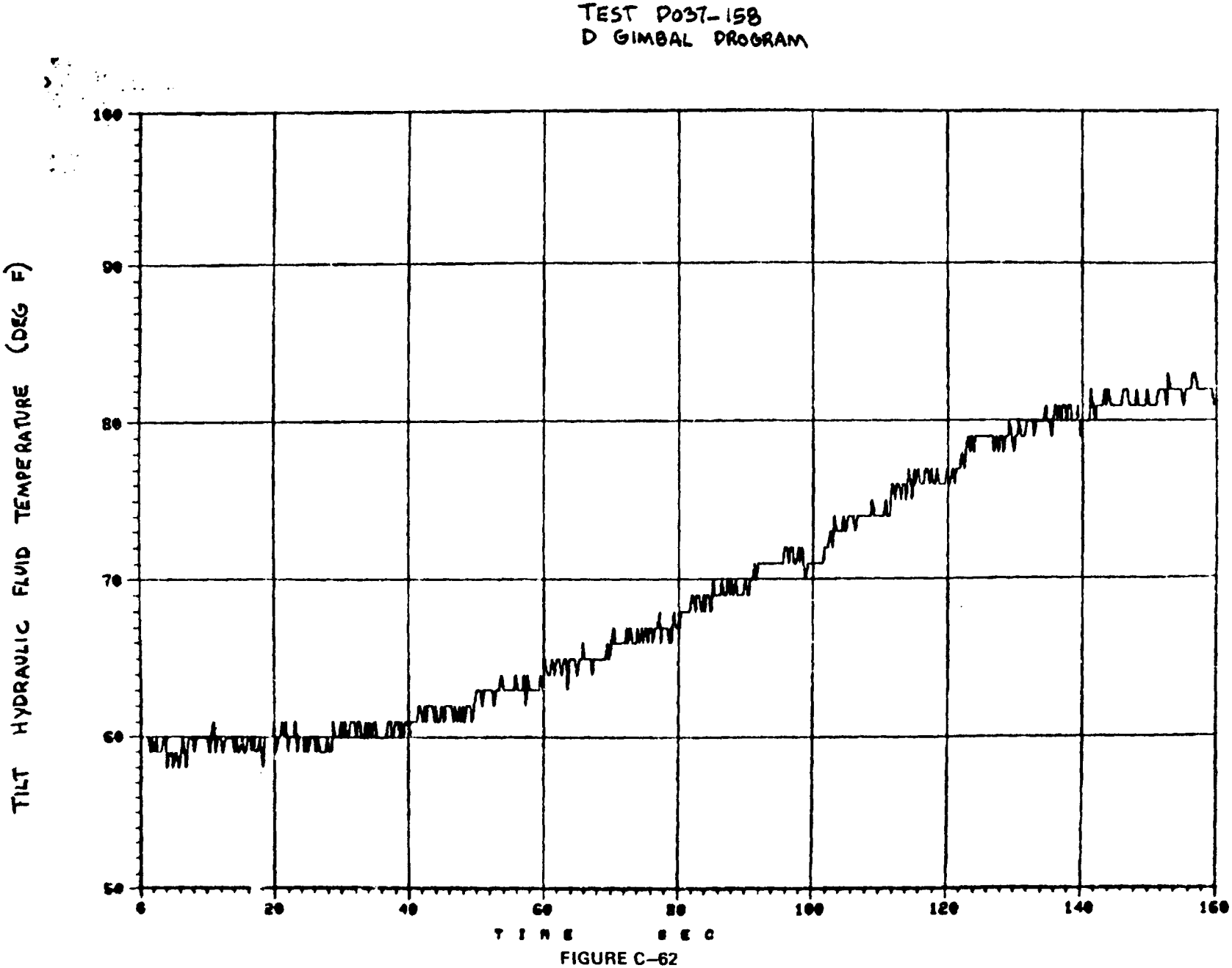

TEST D037-158
D GIMBAL PROGRAM
TILT HYDRAULIC FLUID TEMPERATURE (DEG F)
100
90
80
70
60
50
0
20
40
60
80
100
120
140
160
TIME SEC

FIGURE C–62

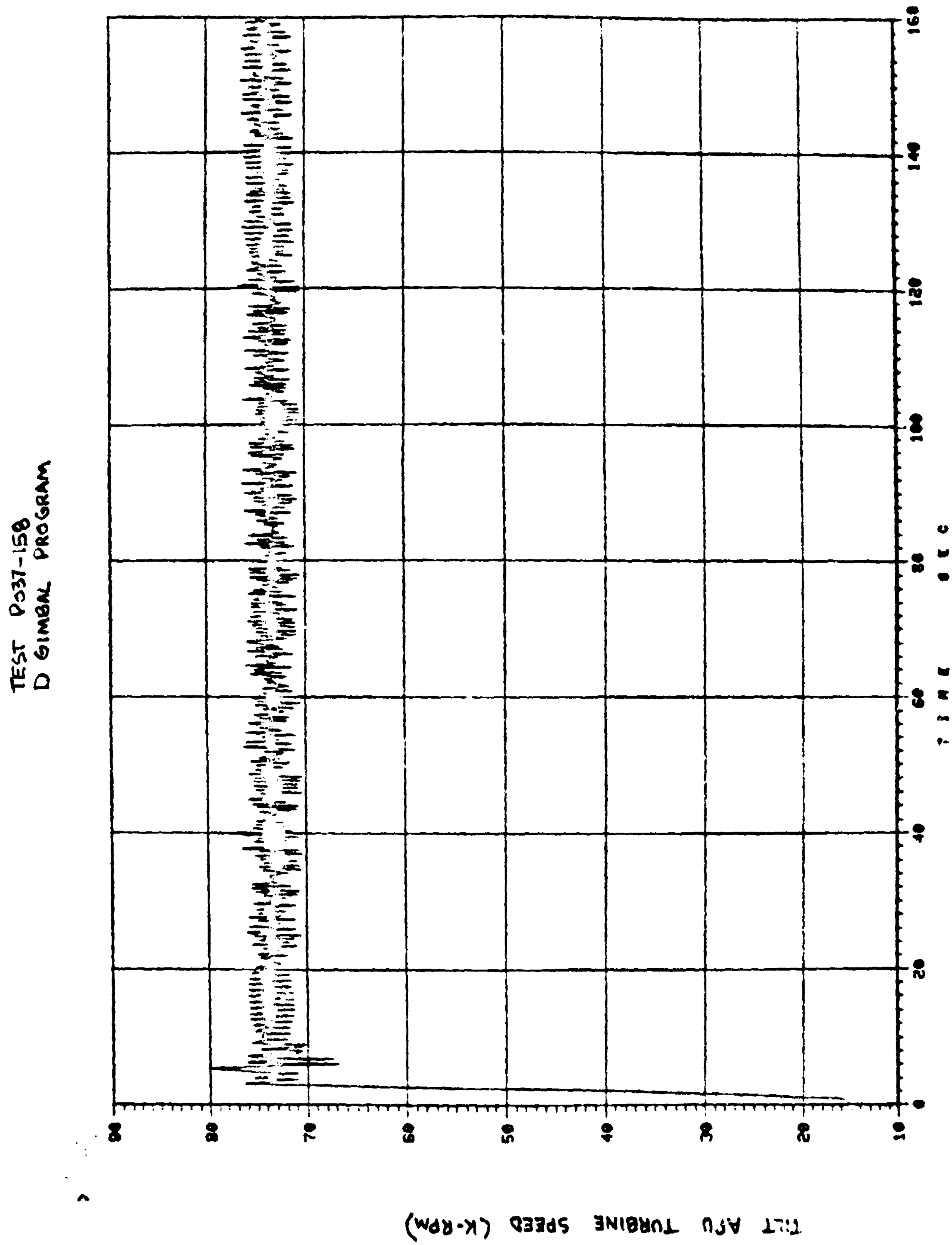


FIGURE C-63

APPENDIX

D

HYDRAULIC FLUID HIGH PRESSURE TRANSIENTS

DURING FREQUENCY RESPONSE

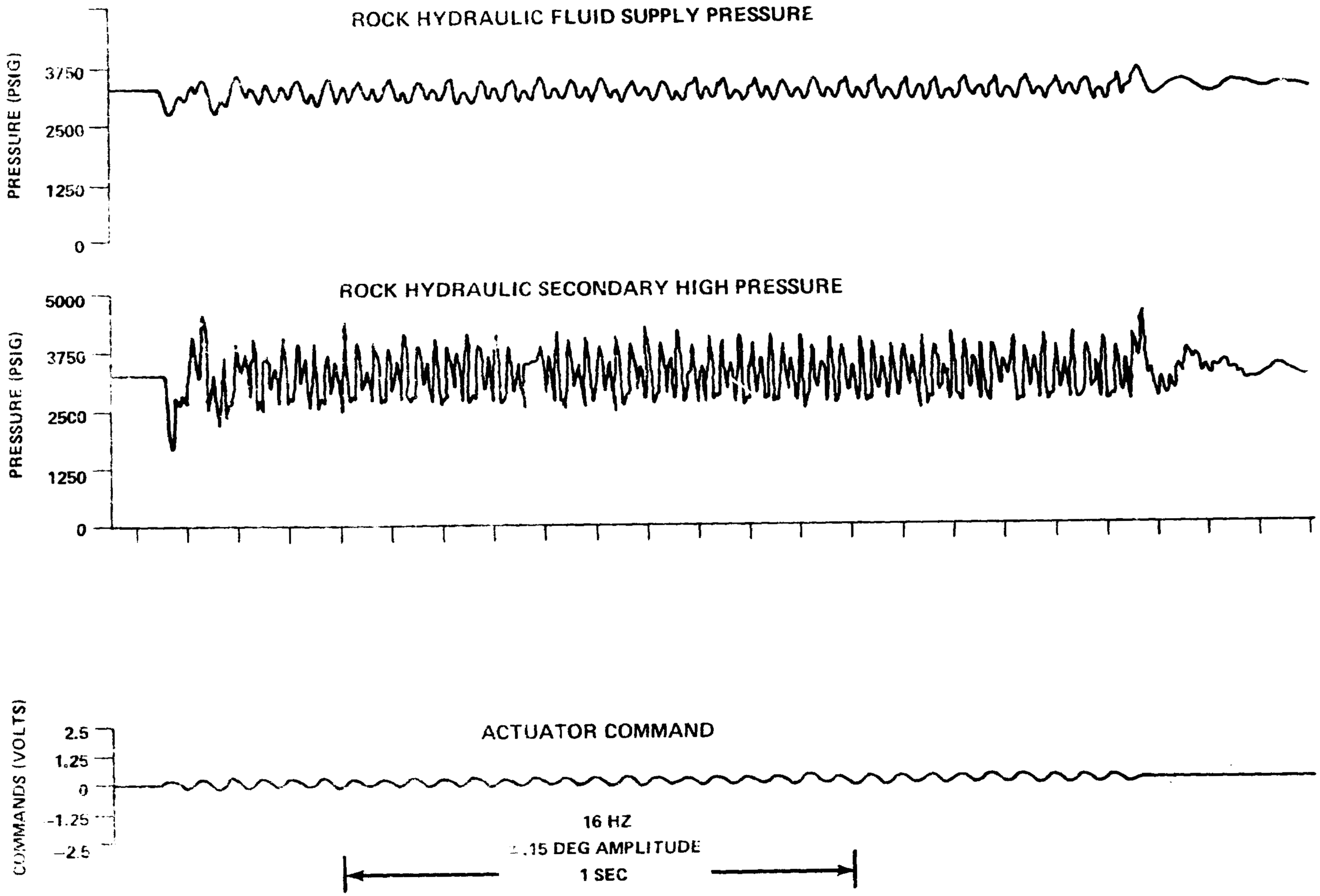

ROCK HYDRAULIC FLUID SUPPLY PRESSURE
PRESSURE (PSIG)
3750
2500
1250
0
ROCK HYDRAULIC SECONDARY HIGH PRESSURE
PRESSURE (PSIG)
5000
3750
2500
1250
0
ACTUATOR COMMAND
COMMANDS (VOLTS)
2.5
1.25
0
-1.25
-2.5
16 HZ
±.15 DEG AMPLITUDE
1 SEC

FIGURE D–1

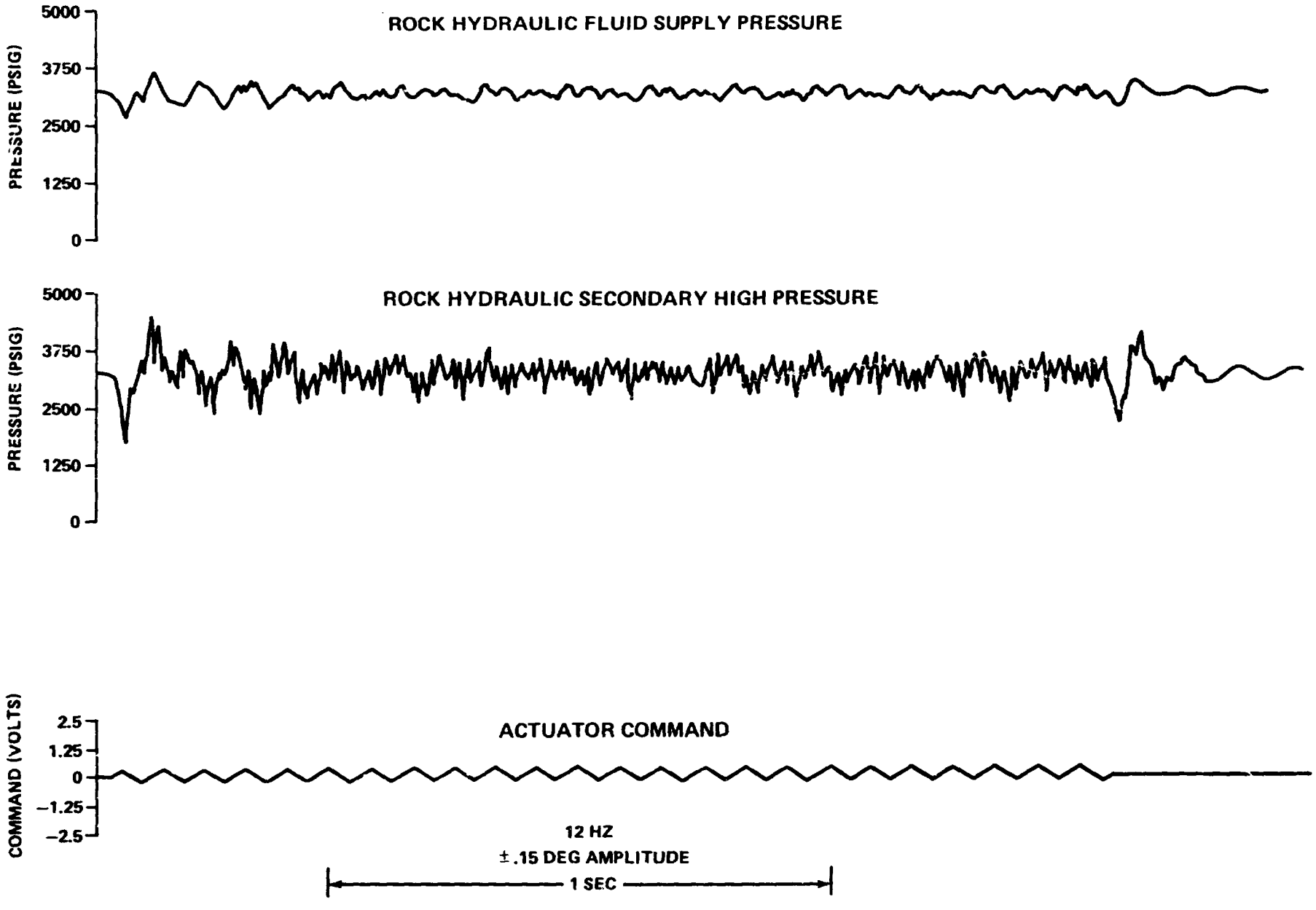

ROCK HYDRAULIC FLUID SUPPLY PRESSURE
PRESSURE (PSIG)
5000
3750
2500
1250
0
ROCK HYDRAULIC SECONDARY HIGH PRESSURE
PRESSURE (PSIG)
5000
3750
2500
1250
0
ACTUATOR COMMAND
COMMAND (VOLTS)
2.5
1.25
0
−1.25
−2.5
12 HZ
±.15 DEG AMPLITUDE
1 SEC

FIGURE D–2

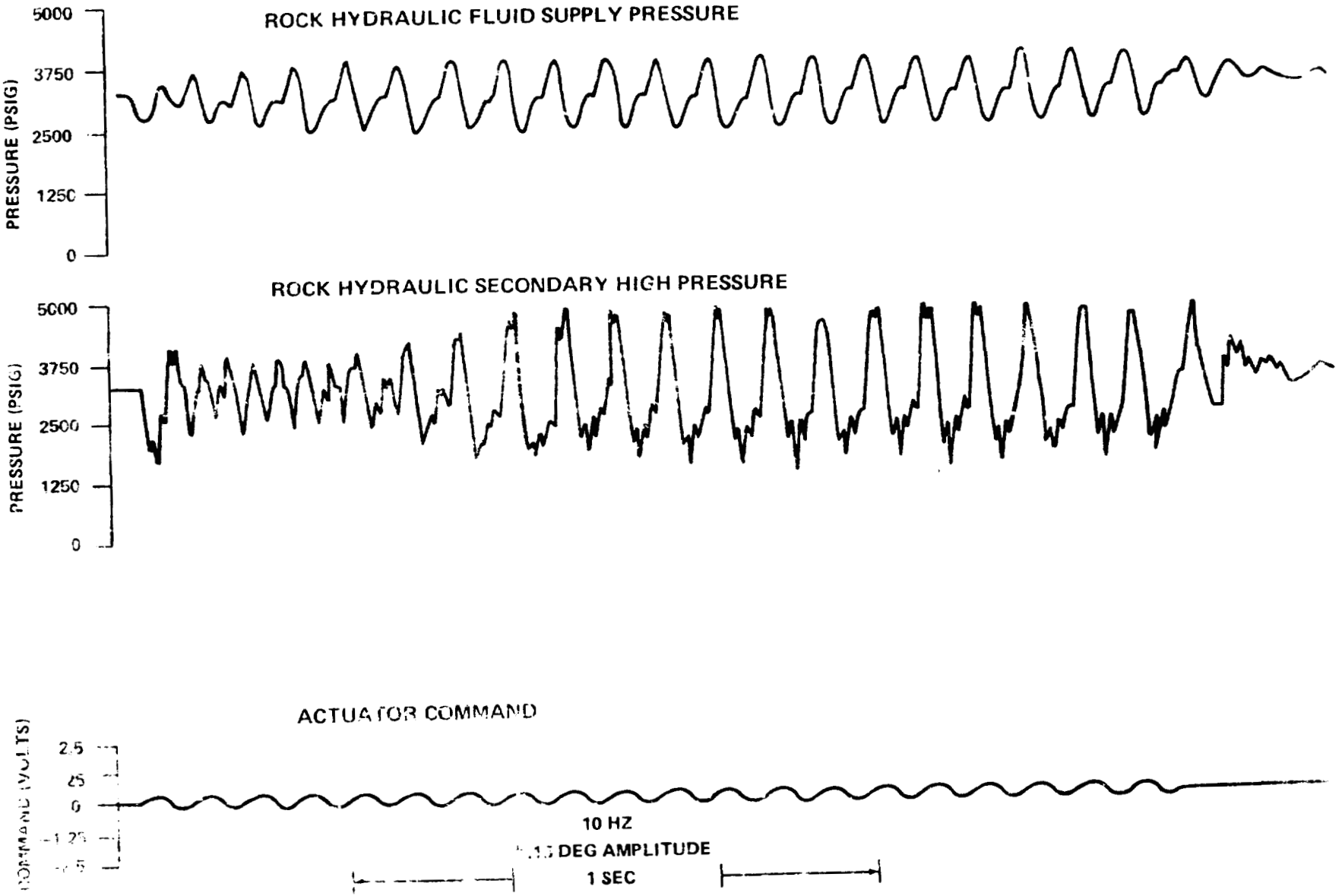

ROCK HYDRAULIC FLUID SUPPLY PRESSURE
PRESSURE (PSIG)
5000
3750
2500
1250
0
ROCK HYDRAULIC SECONDARY HIGH PRESSURE
PRESSURE (PSIG)
5000
3750
2500
1250
0
ACTUATOR COMMAND
2.5
0
10 HZ
1 SEC

FIGURE D–3

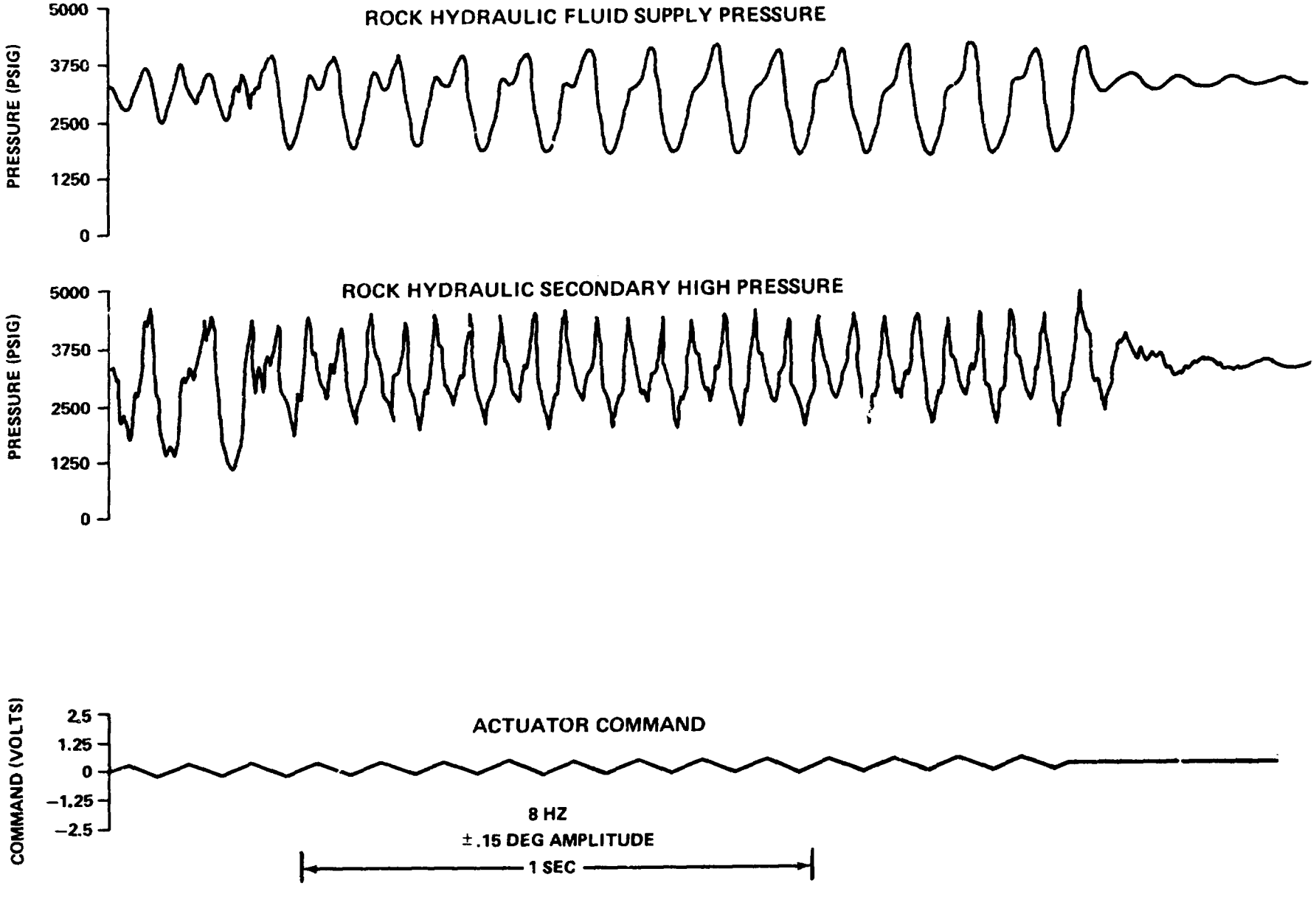

ROCK HYDRAULIC FLUID SUPPLY PRESSURE
PRESSURE (PSIG)
5000
3750
2500
1250
0
ROCK HYDRAULIC SECONDARY HIGH PRESSURE
PRESSURE (PSIG)
5000
3750
2500
1250
0
ACTUATOR COMMAND
COMMAND (VOLTS)
2.5
1.25
0
−1.25
−2.5
8 HZ
± .15 DEG AMPLITUDE
1 SEC

FIGURE D–4

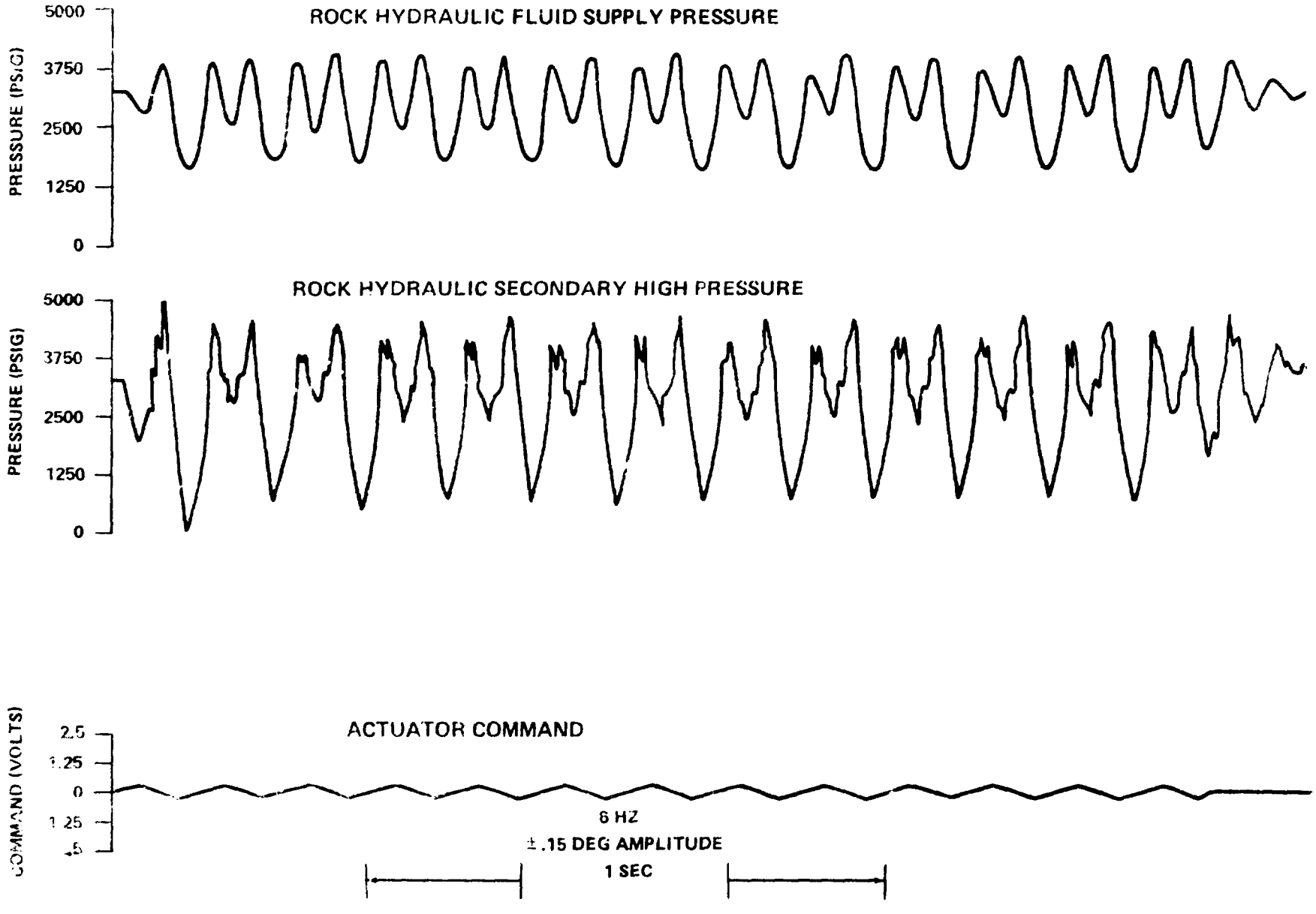

ROCK HYDRAULIC FLUID SUPPLY PRESSURE
PRESSURE (PSIG)
5000
3750
2500
1250
0
ROCK HYDRAULIC SECONDARY HIGH PRESSURE
PRESSURE (PSIG)
5000
3750
2500
1250
0
ACTUATOR COMMAND
COMMAND (VOLTS)
2.5
1.25
0
1.25
6 HZ
±.15 DEG AMPLITUDE
1 SEC

FIGURE D--5

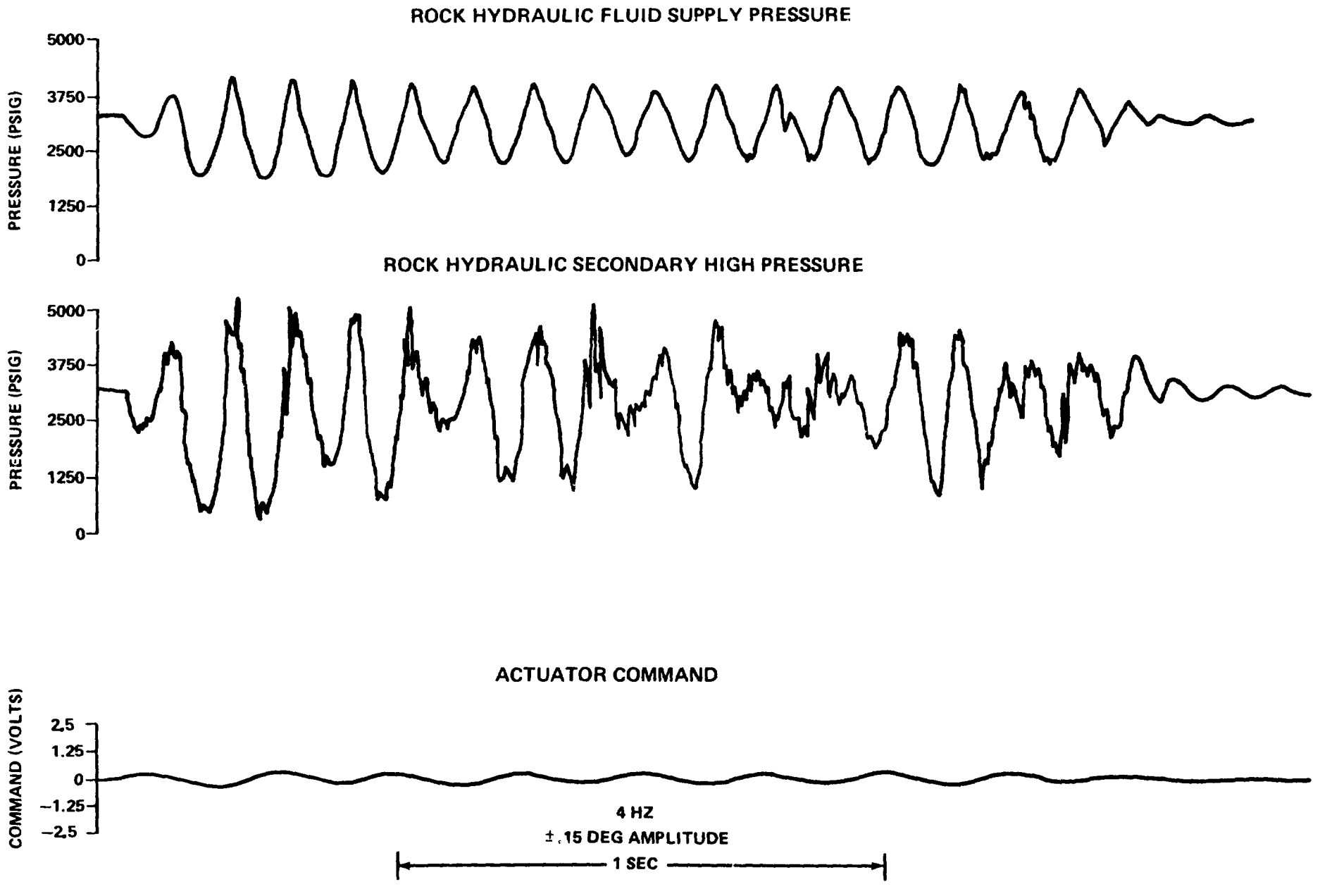

ROCK HYDRAULIC FLUID SUPPLY PRESSURE
PRESSURE (PSIG)
5000
3750
2500
1250
0
ROCK HYDRAULIC SECONDARY HIGH PRESSURE
PRESSURE (PSIG)
5000
3750
2500
1250
0
ACTUATOR COMMAND
COMMAND (VOLTS)
2.5
1.25
0
-1.25
-2.5
4 HZ
±.15 DEG AMPLITUDE
1 SEC

FIGURE D–6

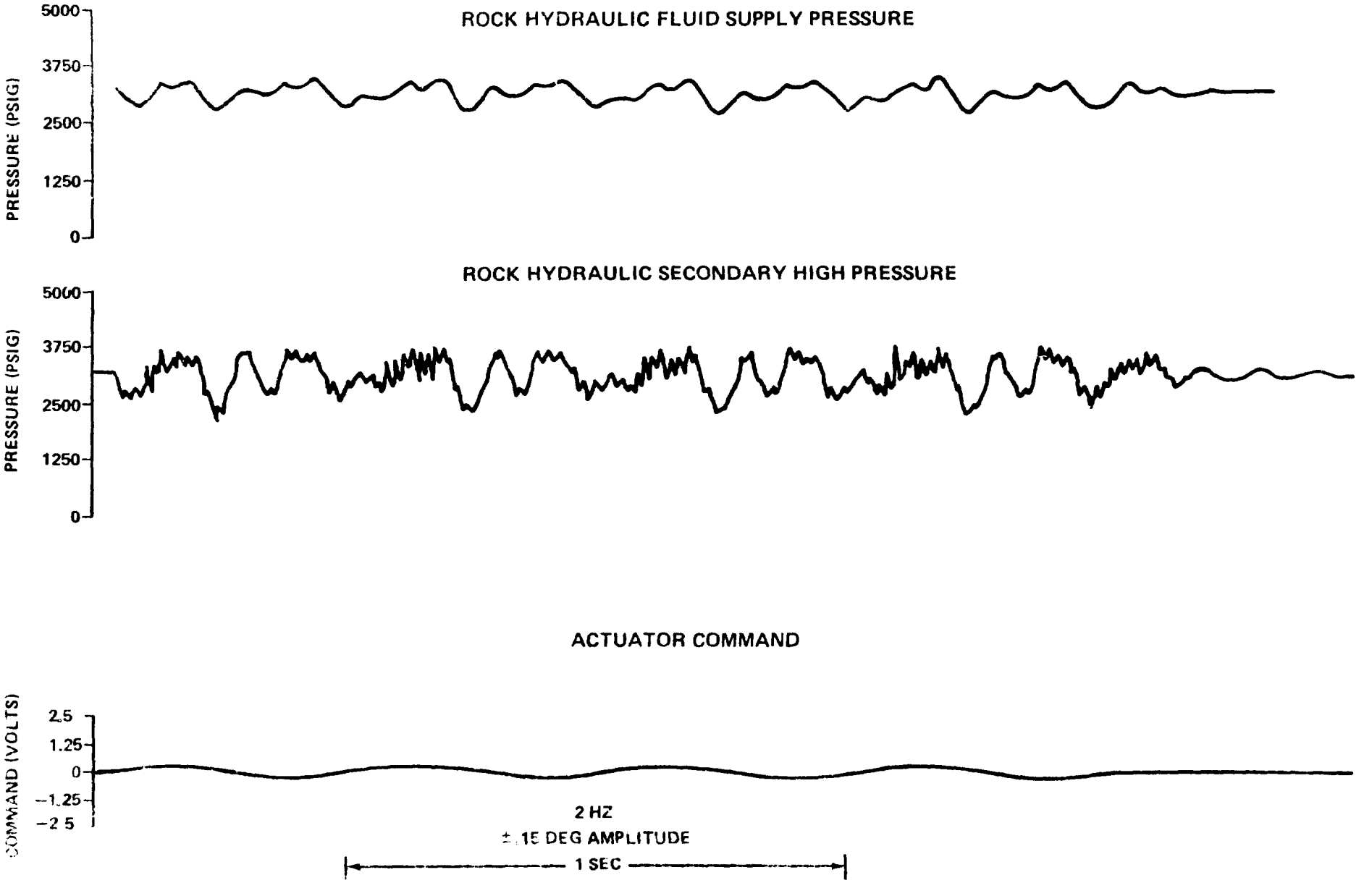

ROCK HYDRAULIC FLUID SUPPLY PRESSURE
PRESSURE (PSIG)
5000
3750
2500
1250
0
ROCK HYDRAULIC SECONDARY HIGH PRESSURE
PRESSURE (PSIG)
5000
3750
2500
1250
0
ACTUATOR COMMAND
COMMAND (VOLTS)
2.5
1.25
0
−1.25
−2.5
2 HZ
± 15 DEG AMPLITUDE
1 SEC

FIGURE D–7

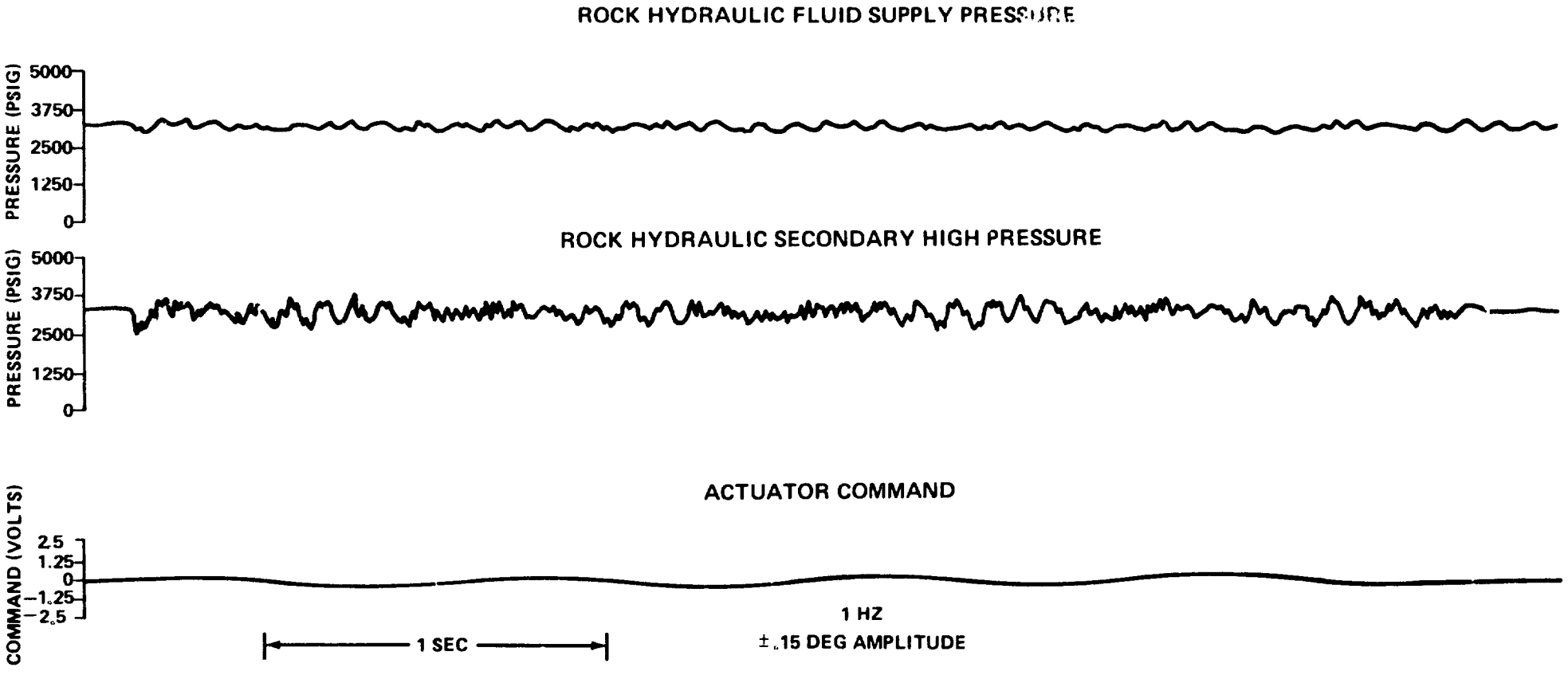

ROCK HYDRAULIC FLUID SUPPLY PRESSURE
PRESSURE (PSIG)
5000
3750
2500
1250
0
ROCK HYDRAULIC SECONDARY HIGH PRESSURE
PRESSURE (PSIG)
5000
3750
2500
1250
0
ACTUATOR COMMAND
COMMAND (VOLTS)
2.5
1.25
0
−1.25
−2.5
1 SEC
1 HZ
±.15 DEG AMPLITUDE

FIGURE D–8

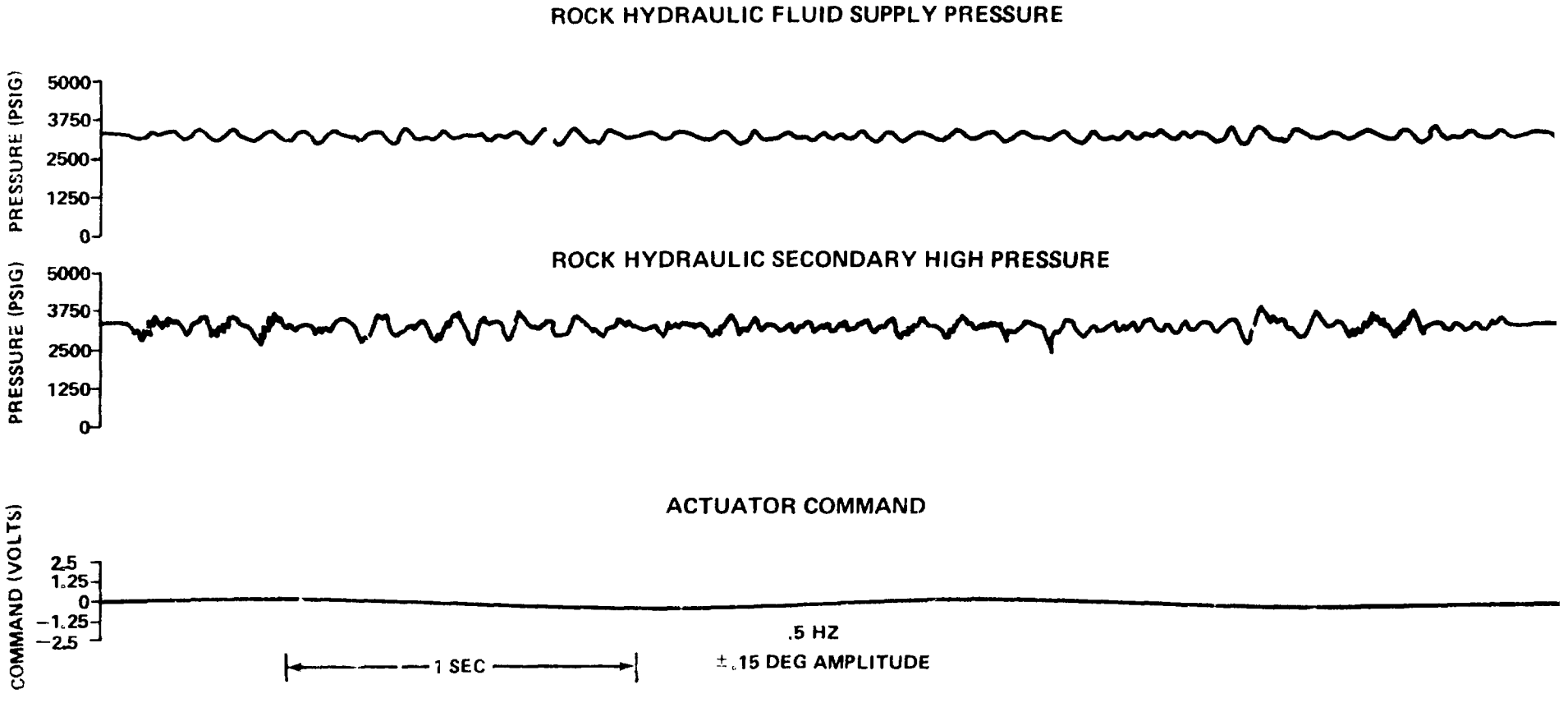

ROCK HYDRAULIC FLUID SUPPLY PRESSURE
PRESSURE (PSIG)
5000
3750
2500
1250
0
ROCK HYDRAULIC SECONDARY HIGH PRESSURE
PRESSURE (PSIG)
5000
3750
2500
1250
0
ACTUATOR COMMAND
COMMAND (VOLTS)
2.5
1.25
0
−1.25
−2.5
1 SEC
.5 HZ
±.15 DEG AMPLITUDE

FIGURE D–9

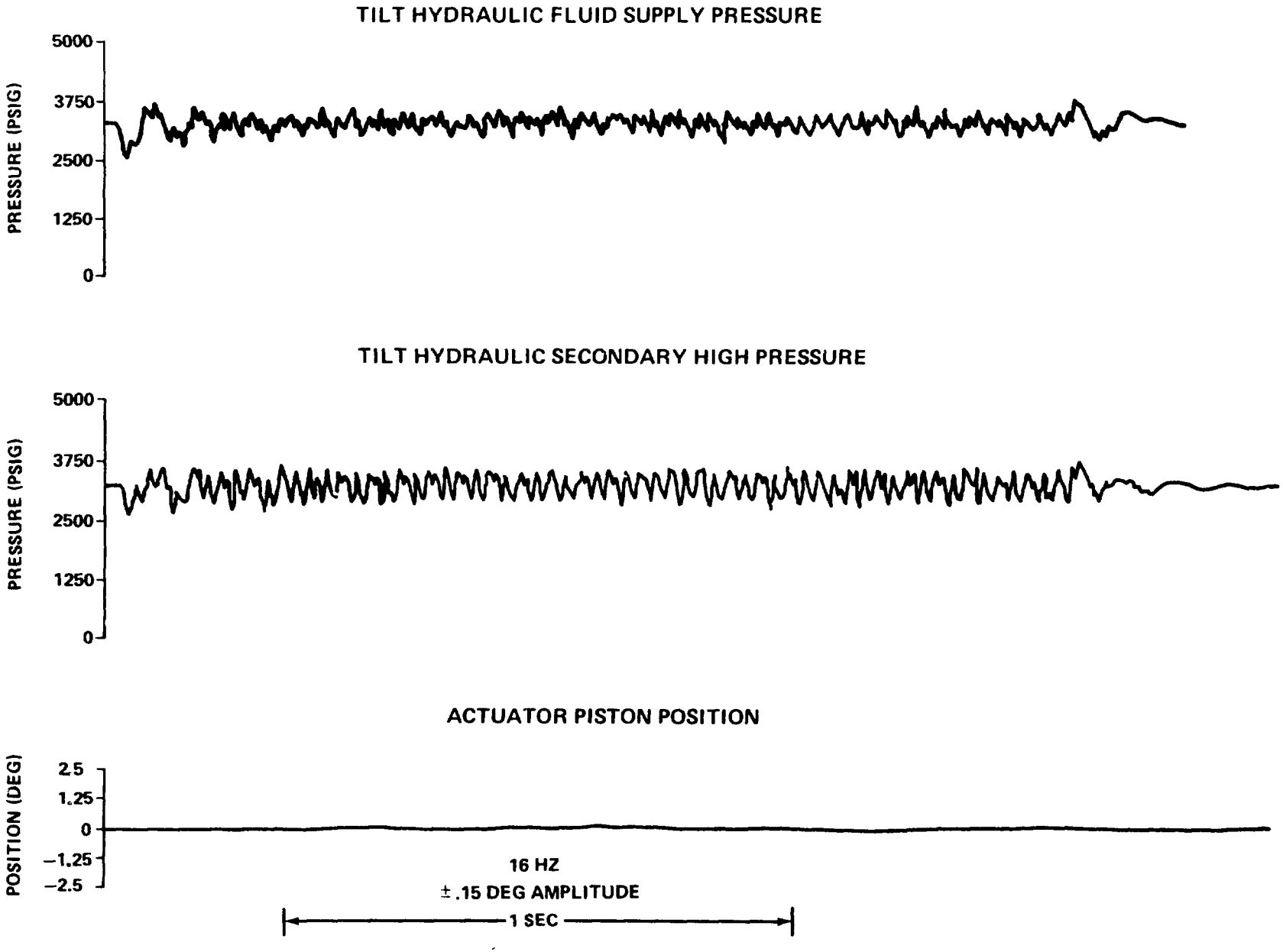

TILT HYDRAULIC FLUID SUPPLY PRESSURE
PRESSURE (PSIG)
5000
3750
2500
1250
0
TILT HYDRAULIC SECONDARY HIGH PRESSURE
PRESSURE (PSIG)
5000
3750
2500
1250
0
ACTUATOR PISTON POSITION
POSITION (DEG)
2.5
1.25
0
−1.25
−2.5
16 HZ
±.15 DEG AMPLITUDE
1 SEC

FIGURE D–10

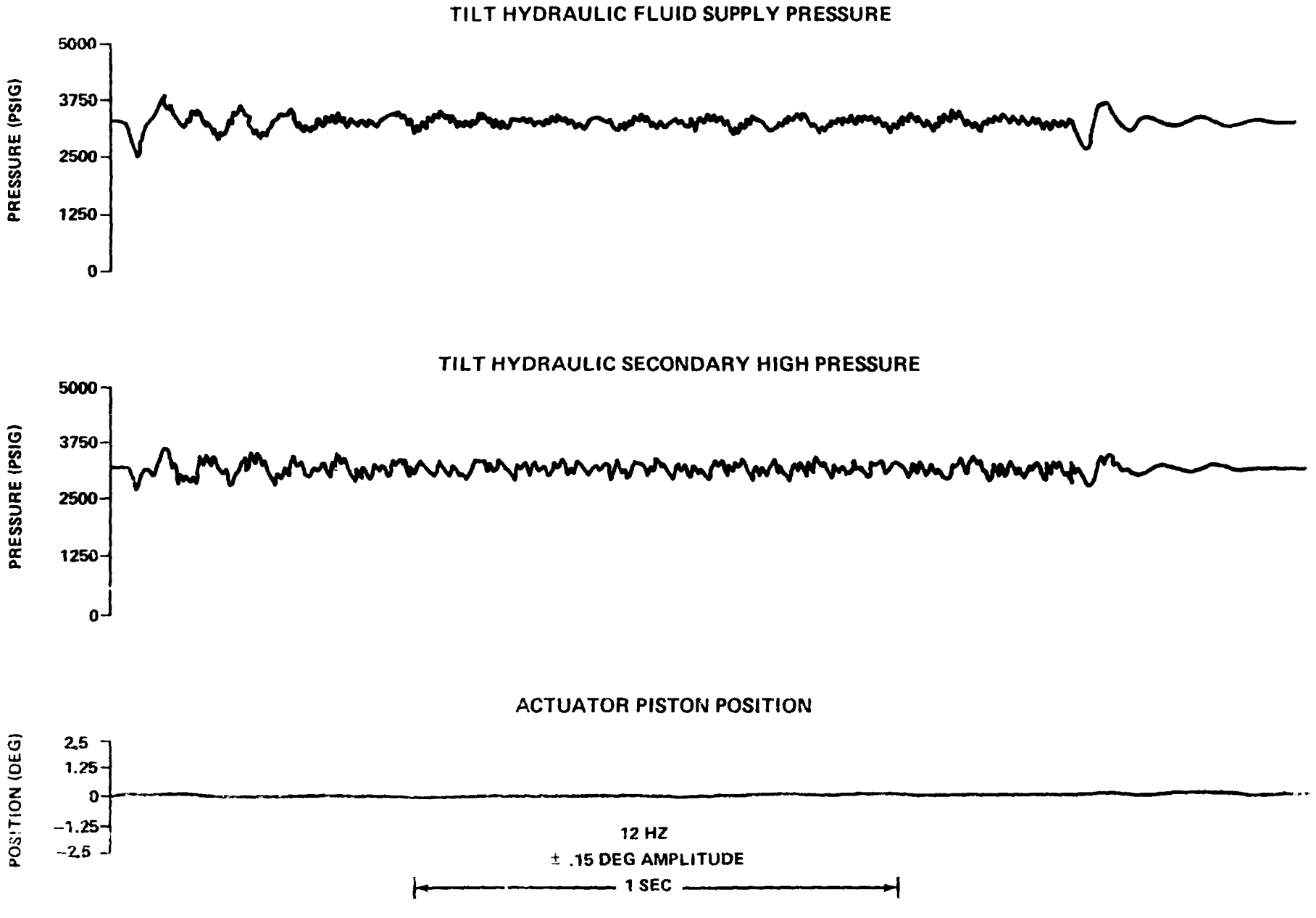

TILT HYDRAULIC FLUID SUPPLY PRESSURE
PRESSURE (PSIG)
5000
3750
2500
1250
0
TILT HYDRAULIC SECONDARY HIGH PRESSURE
PRESSURE (PSIG)
5000
3750
2500
1250
0
ACTUATOR PISTON POSITION
POSITION (DEG)
2.5
1.25
0
-1.25
-2.5
12 HZ
± .15 DEG AMPLITUDE
1 SEC

FIGURE D–11

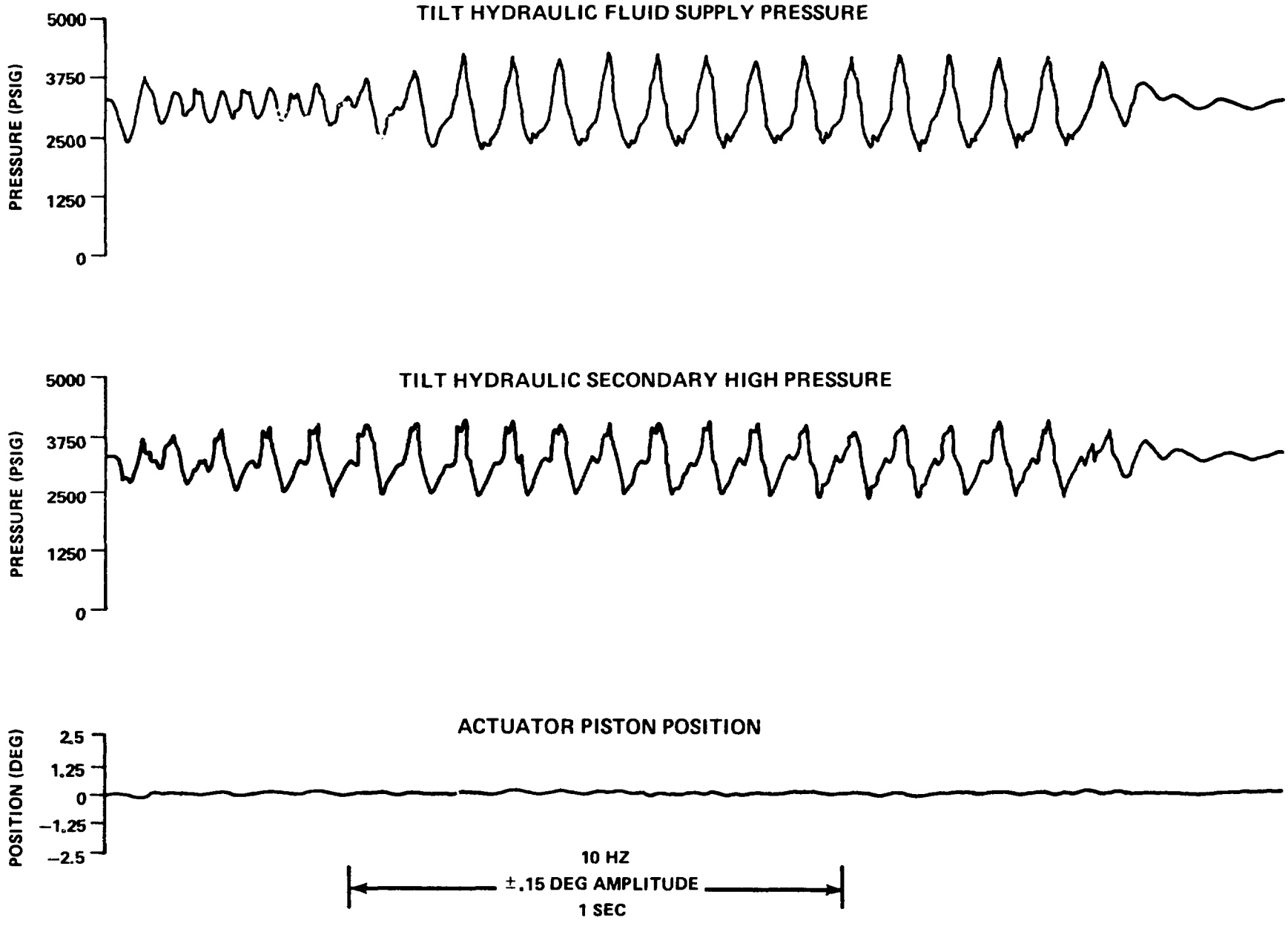

TILT HYDRAULIC FLUID SUPPLY PRESSURE
PRESSURE (PSIG)
5000
3750
2500
1250
0
TILT HYDRAULIC SECONDARY HIGH PRESSURE
PRESSURE (PSIG)
5000
3750
2500
1250
0
ACTUATOR PISTON POSITION
POSITION (DEG)
2.5
1.25
0
−1.25
−2.5
10 HZ
±.15 DEG AMPLITUDE
1 SEC

FIGURE D–12

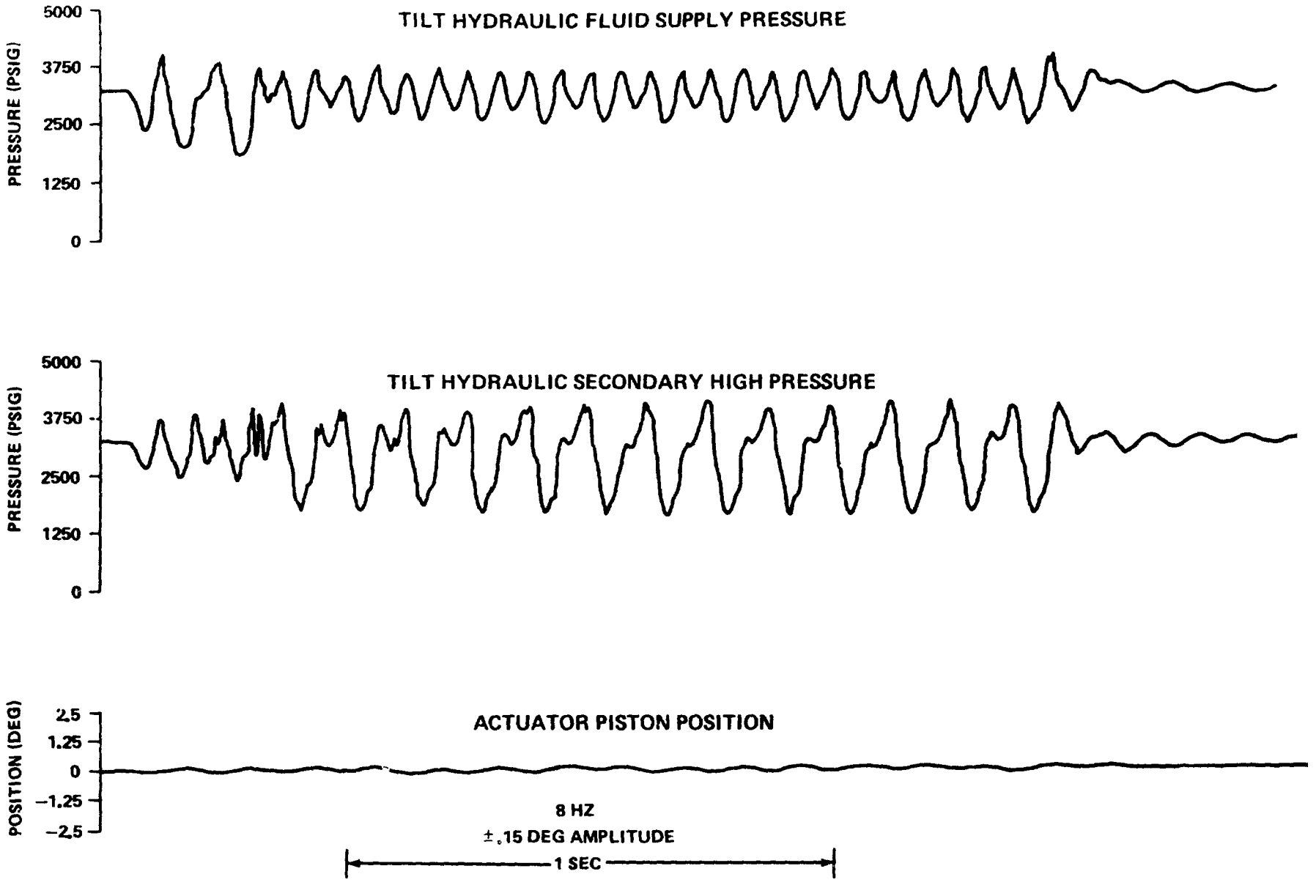

TILT HYDRAULIC FLUID SUPPLY PRESSURE
PRESSURE (PSIG)
5000
3750
2500
1250
0
TILT HYDRAULIC SECONDARY HIGH PRESSURE
PRESSURE (PSIG)
5000
3750
2500
1250
0
ACTUATOR PISTON POSITION
POSITION (DEG)
2.5
1.25
0
−1.25
−2.5
8 HZ
±.15 DEG AMPLITUDE
1 SEC

FIGURE D–13

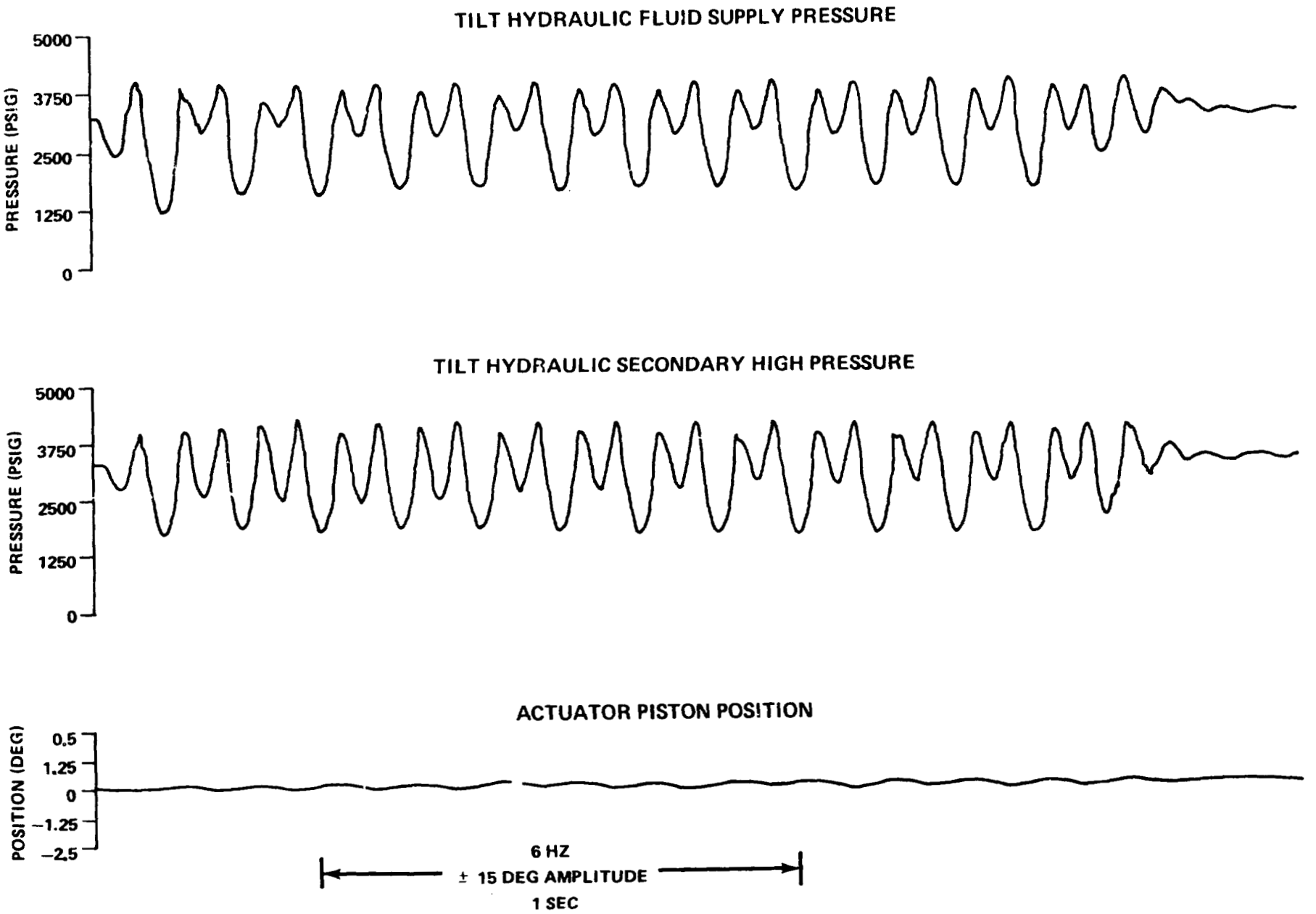

TILT HYDRAULIC FLUID SUPPLY PRESSURE
PRESSURE (PSIG)
5000
3750
2500
1250
0
TILT HYDRAULIC SECONDARY HIGH PRESSURE
PRESSURE (PSIG)
5000
3750
2500
1250
0
ACTUATOR PISTON POSITION
POSITION (DEG)
0.5
1.25
0
−1.25
−2.5
6 HZ
± 15 DEG AMPLITUDE
1 SEC

FIGURE D–14

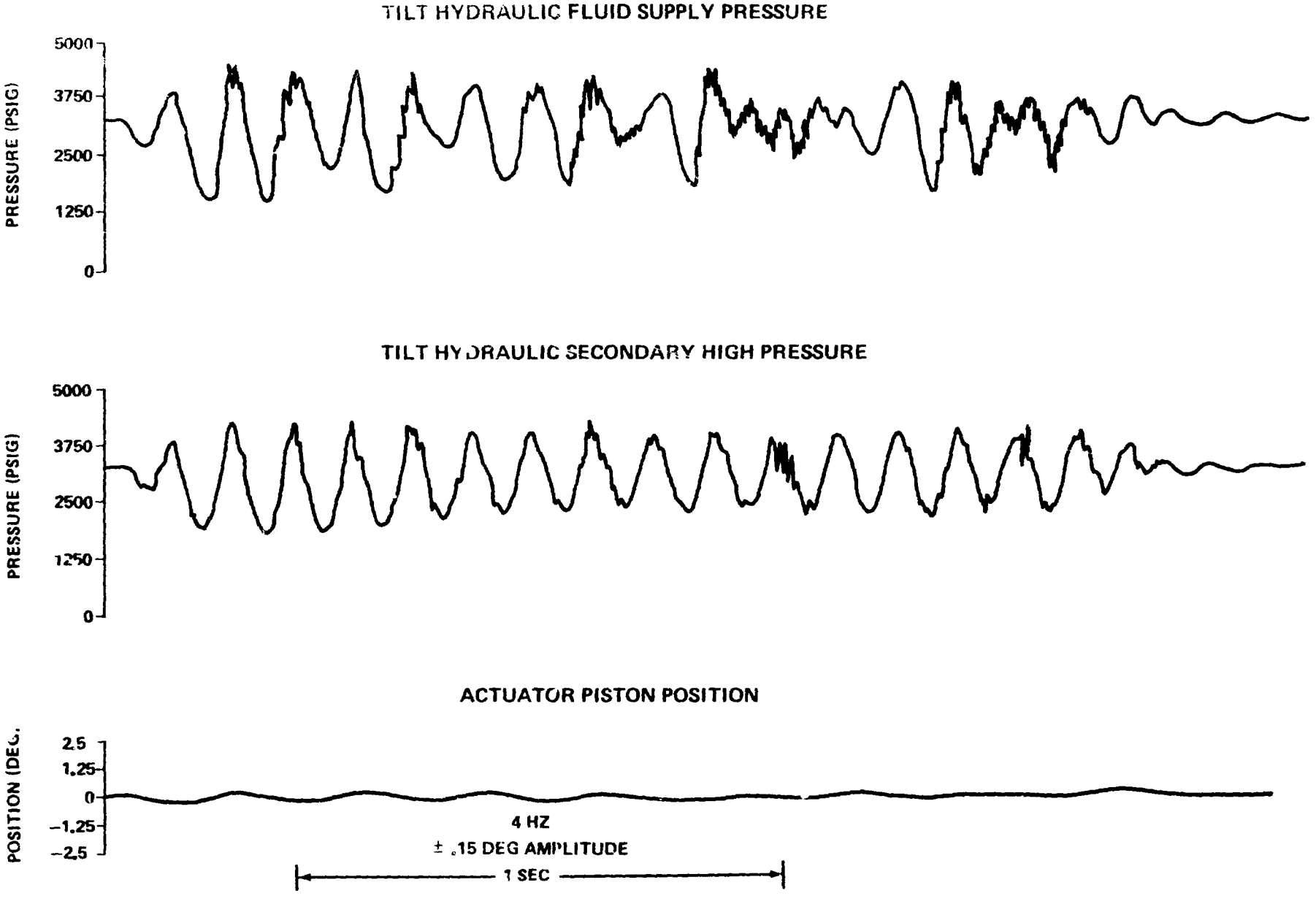

TILT HYDRAULIC FLUID SUPPLY PRESSURE
PRESSURE (PSIG)
5000
3750
2500
1250
0
TILT HYDRAULIC SECONDARY HIGH PRESSURE
PRESSURE (PSIG)
5000
3750
2500
1250
0
ACTUATOR PISTON POSITION
POSITION (DEG.
2.5
1.25
0
-1.25
-2.5
4 HZ
± .15 DEG AMPLITUDE
1 SEC

FIGURE D–15

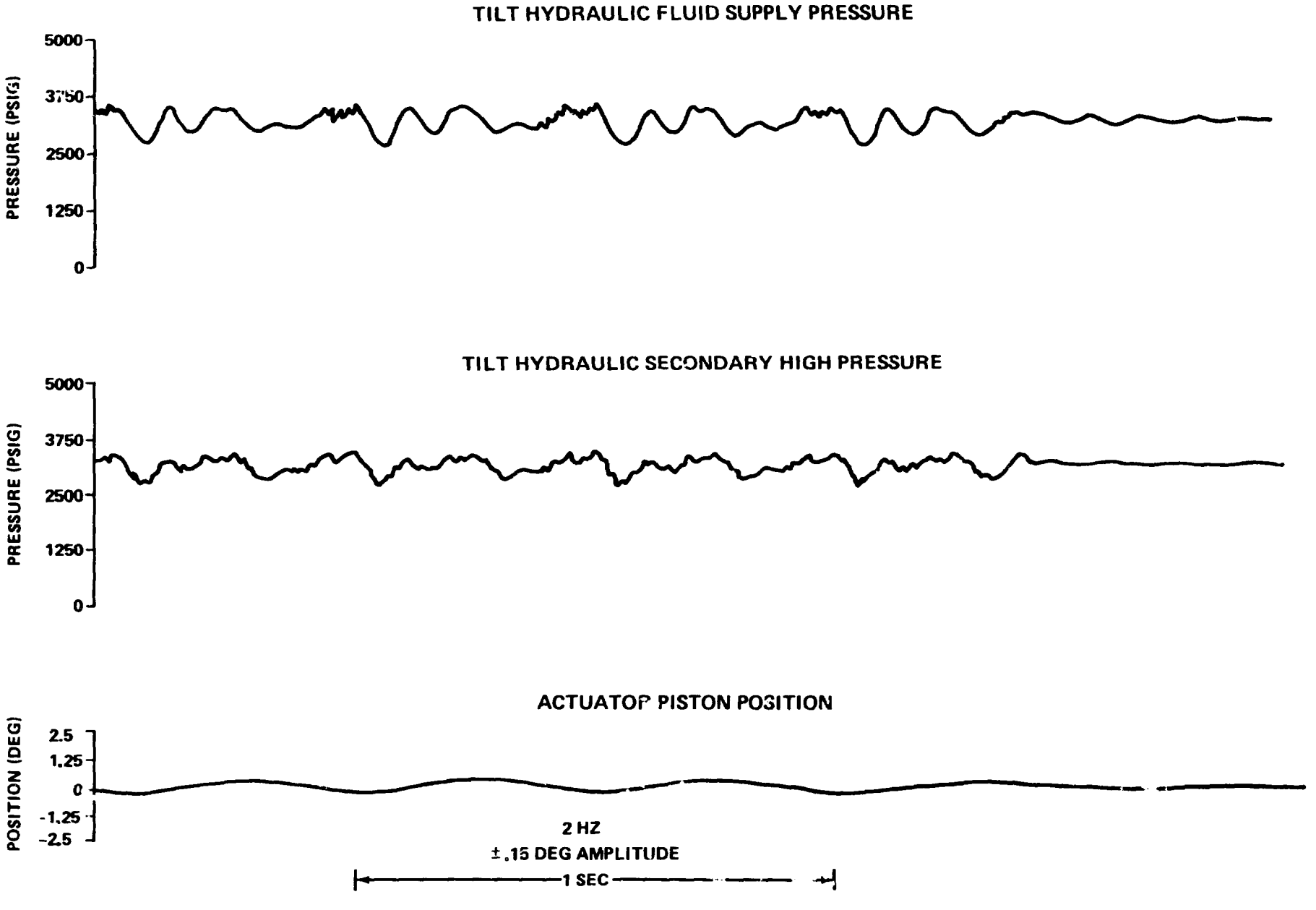

TILT HYDRAULIC FLUID SUPPLY PRESSURE
PRESSURE (PSIG)
5000
3750
2500
1250
0
TILT HYDRAULIC SECONDARY HIGH PRESSURE
PRESSURE (PSIG)
5000
3750
2500
1250
0
ACTUATOR PISTON POSITION
POSITION (DEG)
2.5
1.25
0
-1.25
-2.5
2 HZ
±.15 DEG AMPLITUDE
1 SEC

FIGURE D–16

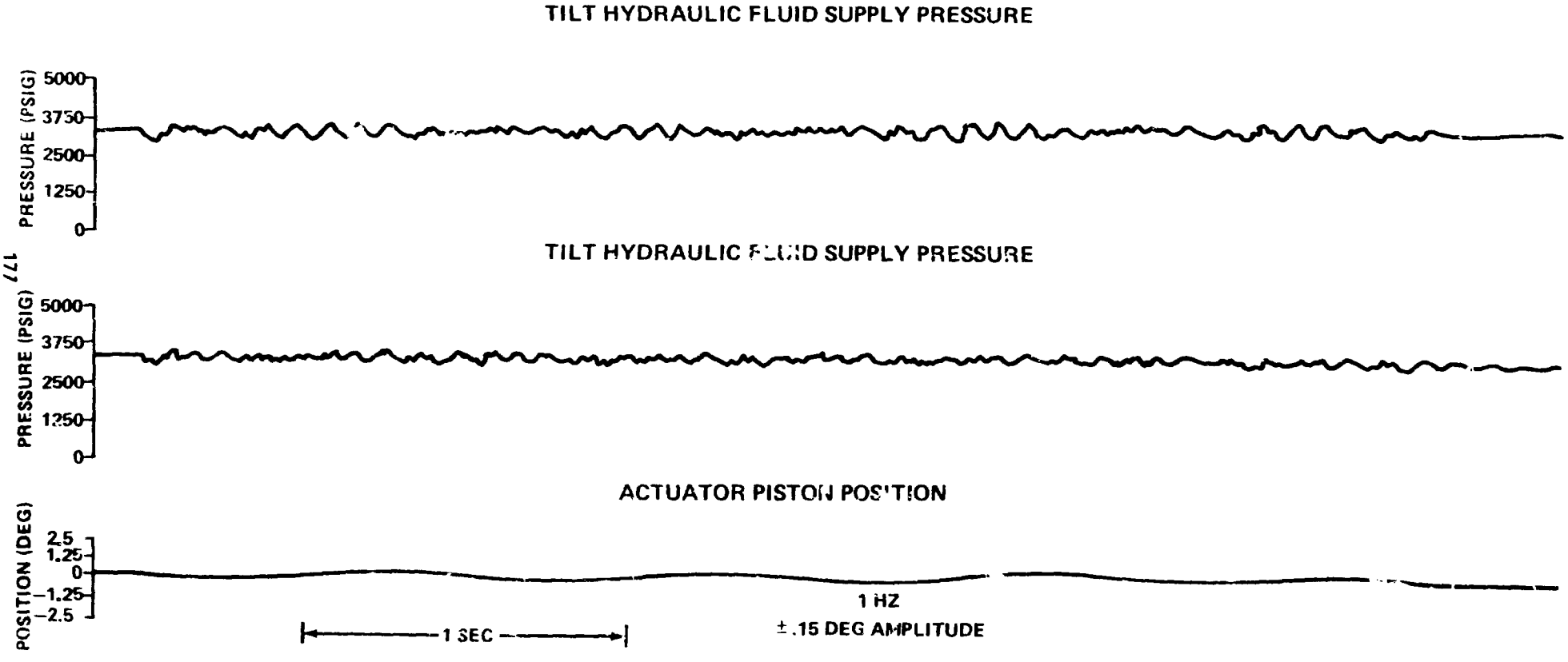

TILT HYDRAULIC FLUID SUPPLY PRESSURE
PRESSURE (PSIG)
5000
3750
2500
1250
0
TILT HYDRAULIC FLUID SUPPLY PRESSURE
PRESSURE (PSIG)
5000
3750
2500
1250
0
ACTUATOR PISTON POSITION
POSITION (DEG)
2.5
1.25
0
−1.25
−2.5
1 SEC
1 HZ
±.15 DEG AMPLITUDE

FIGURE D–17

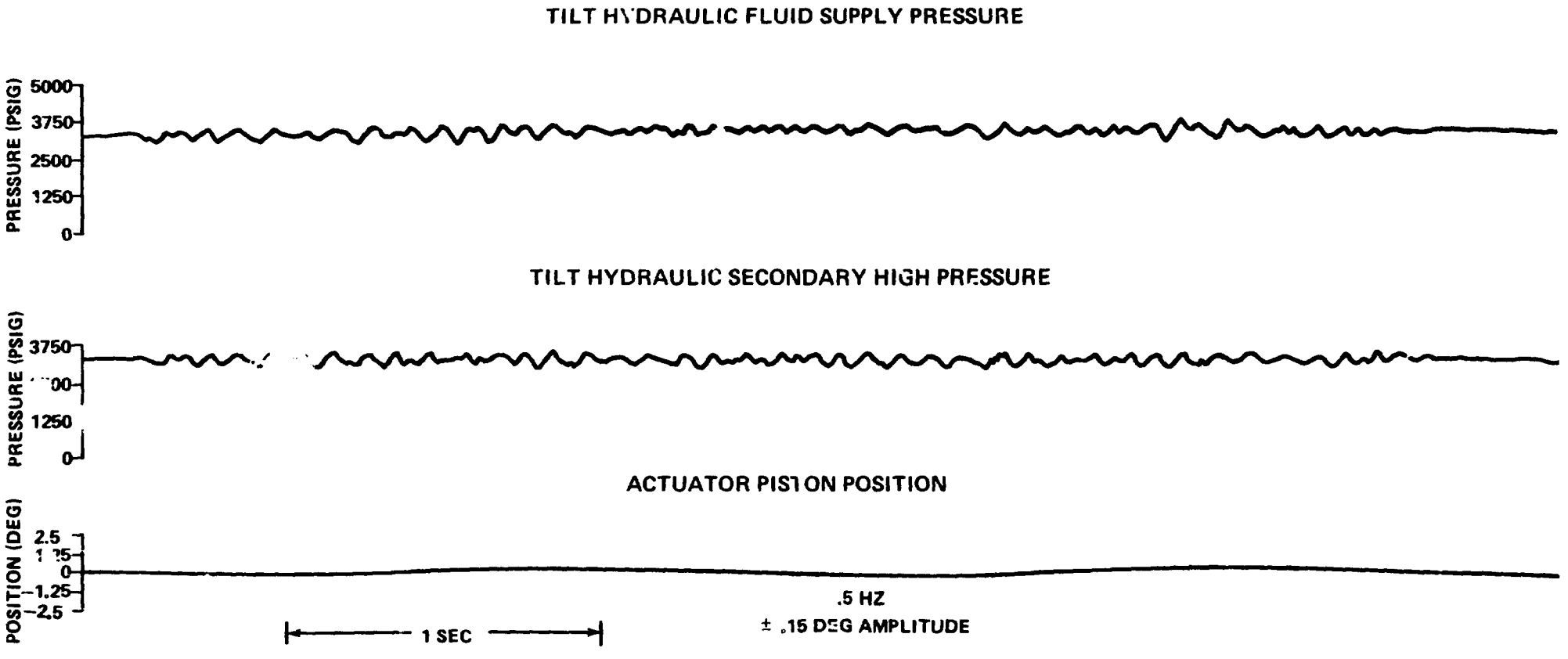

TILT HYDRAULIC FLUID SUPPLY PRESSURE
PRESSURE (PSIG)
5000
3750
2500
1250
0
TILT HYDRAULIC SECONDARY HIGH PRESSURE
PRESSURE (PSIG)
3750
1250
0
ACTUATOR PISTON POSITION
POSITION (DEG)
2.5
1.25
0
-1.25
-2.5
1 SEC
.5 HZ
± .15 DEG AMPLITUDE

FIGURE D–18

APPENDIX

E

SELECTED

GN_2 SPIN DATA

B1 GIMBAL PROGRAM

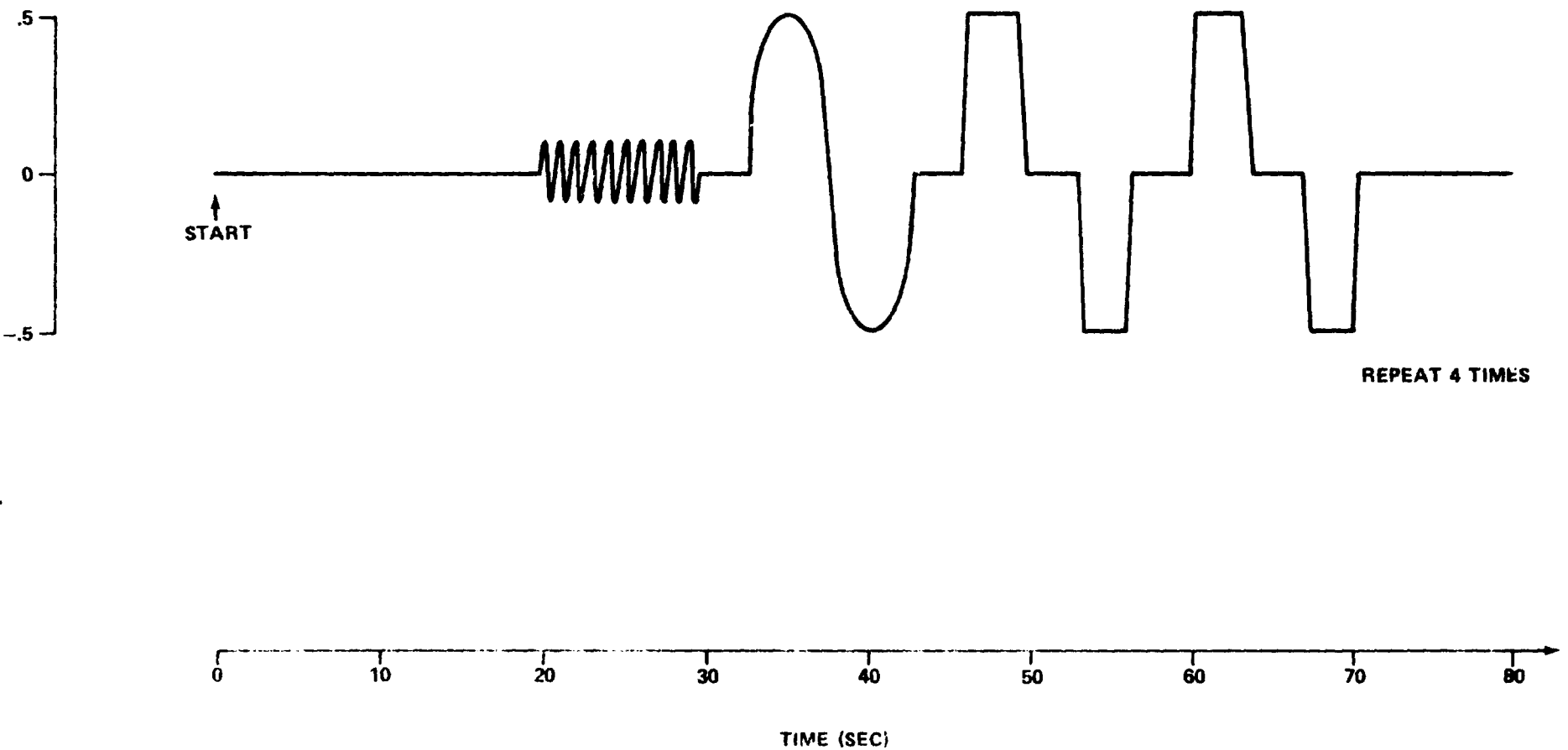


FIGURE E-1

TEST P037–199 (GN_2 SPIN)
TILT SYSTEM

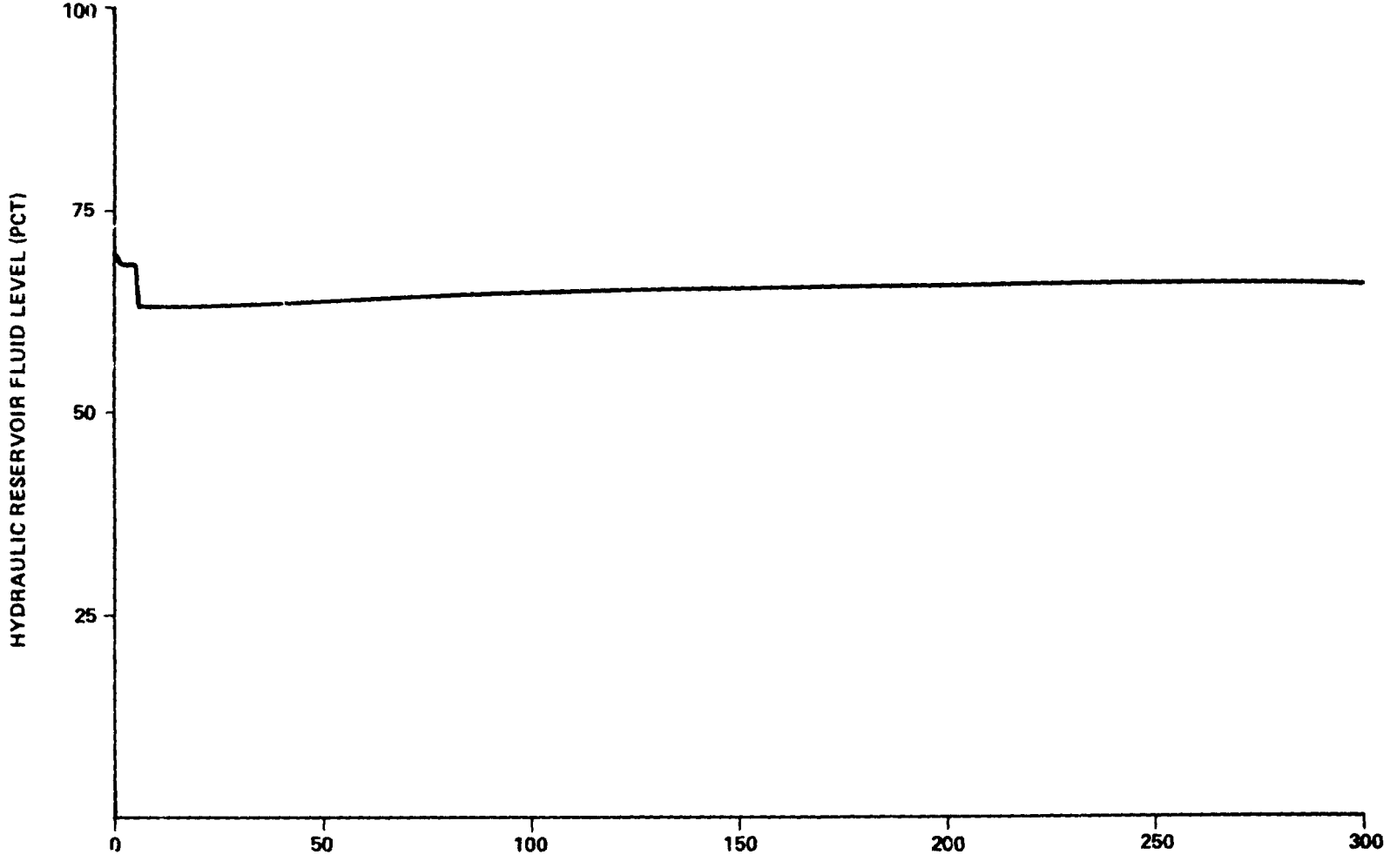


FIGURE E–2

TEST P037–199 (GN_2 SPIN)
TILT SYSTEM

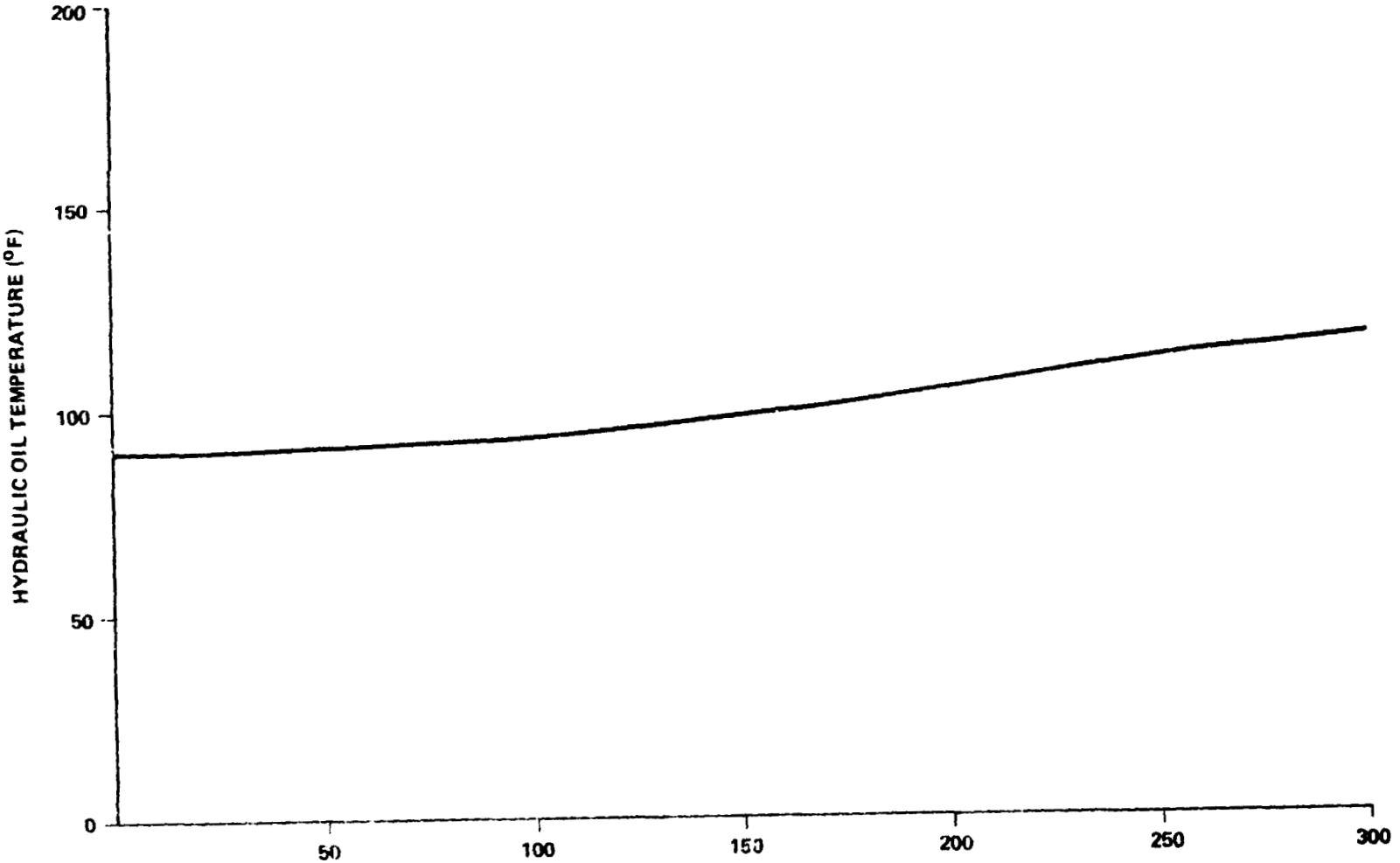


FIGURE E–3

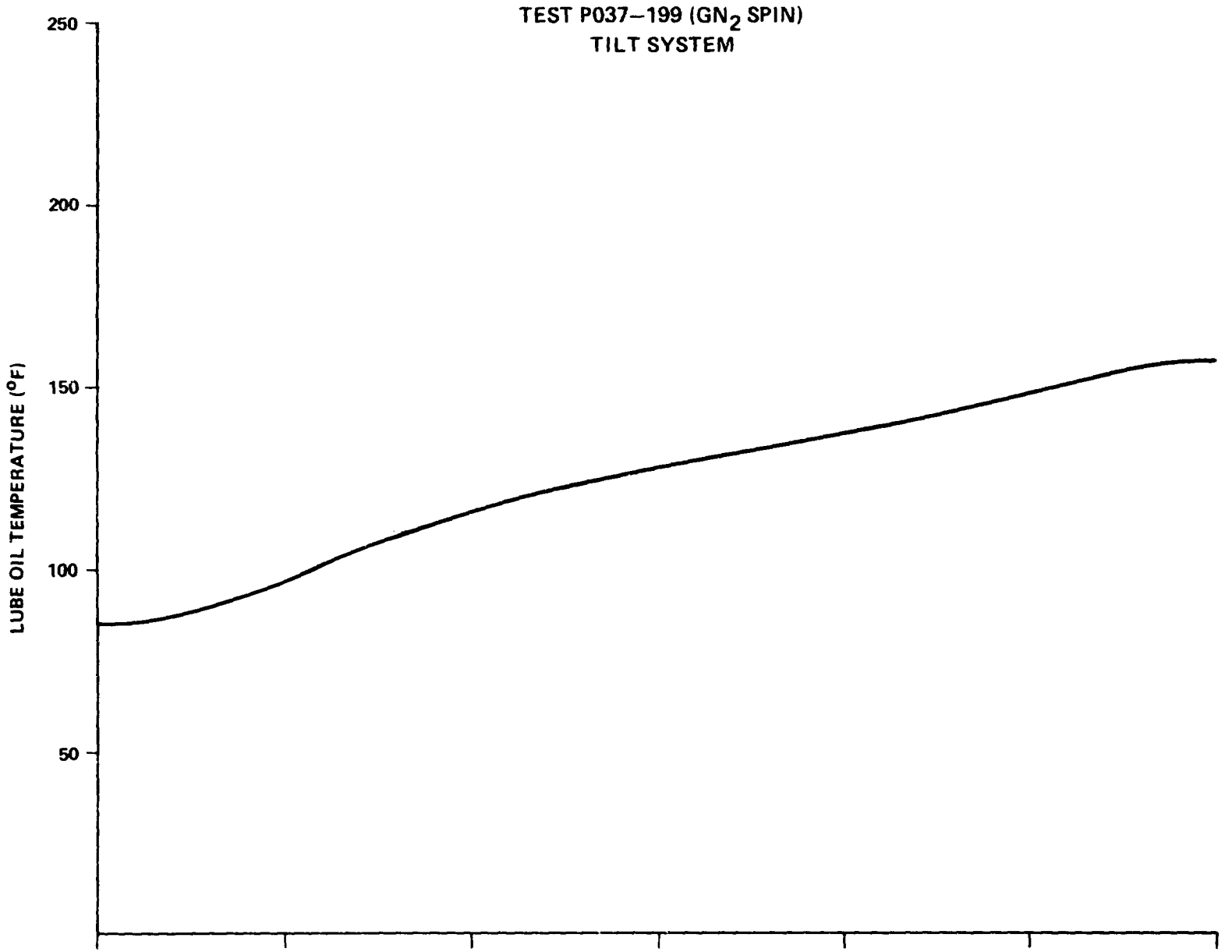

TEST P037–199 (GN_2 SPIN)
TILT SYSTEM
LUBE OIL TEMPERATURE (°F)
250
200
150
100
50
0
50
100
150
200
250
300
TIME (SEC)

FIGURE E–4

APPROVAL

SOLID ROCKET BOOSTER

THRUST VECTOR CONTROL

SUBSYSTEM VERIFICATION TEST (V-2)

REPORT

The information in this report has been reviewed for security classification. Review of any information concerning Department of Defense or nuclear energy activities or programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified.

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